Popular Astronomy.

Vol. XIX, No. 6. JUNE-JULY, 1911. Whole No., 186

METHODS OF SILVERING MIRRORS.*

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The different processes which have been discovered for depositing a thin film of silver on glass are widely scattered in periodical literature and laboratory manuals. Some of these processes are now rarely employed, and even for the more modern methods which have proved most uniformly successful, the experience of those who have had extensive practice in silvering large mirrors will without doubt be of assistance to the amateur. The manipulation has been described by some as very uncertain and of considerable difficulty. It will be found, however, that by using pure chemicals and carefully following the directions, successful coats can nearly always be secured. Occasionally a failure will result for which no reason can be assigned. The writer has had one such experience, with the secondary mirror of the Santiago reflector, which was an absolute failure, though silvered on the same day, with the same process, and as far as was known with exactly the same manipulation which gave an excellent coat on the primary. I think that most manipulators will feel a tendency to echo the words of Quincke,—written half a century ago, it is true, when silvering processes were much less reliable than at present: "Uebrigens versagen zuweilen alle diese Methoden, oder liefern doch fehlerhafte Spiegel, ohne dass ein rechter Grund dafür auszufinden wäre."

Siemens is said to have expressed his disbelief that any process of depositing silver from a solution could ever be discovered. Many processes have been evolved since that date, practically all of them with an ammoniated solution of nitrate of silver as a basis, the differences lying in the character of the organic reducing medium employed. Glucose, milk sugar, acid-

* Reprinted from the *Publications of the Astronomical Society of the Pacific* Vol. xxiii, February, 1911.

ulated levulose, the juices of berries, formaldehyde, Rochelle salts, etc., have all been used. Practically all to-day use either Brashear's or Lundin's methods, but some of the older methods will be given as well. The preparation of the mirror for the process is common to all methods, and will be treated first.

CLEANING THE MIRROR.

The mirror should be carefully freed from dust, and the old coat removed with nitric acid, which is also the best medium for cleaning any glass surface to be silvered for the first time. A thick swab of cotton wool is formed about the end of a glass rod, so that there is no danger of the glass rod scratching the mirror. Provided the swab is thick enough, plenty of pressure may be employed. Swab *every* part thoroughly; when the coat is all off add a little distilled water to the nitric acid already applied and go over the entire surface again. Do not let any part of the mirror become dry during the process; if any part should get dry, swab and clean again. Then rinse off the nitric acid, for which ordinary water may be used at first, followed by distilled water. Finally leave the mirror standing with a covering of distilled water over its surface; no part should be allowed to become dry.

Small mirrors may be advantageously silvered face down, resting on three thin wedges of wood cemented to the bottom of a shallow pan. For mirrors eight inches or over in diameter, however, I generally silver face up. In the case of the mirror of the Crossley reflector the preparation is as follows: The mirror is removed from its cell and supported in a ring equipped with trunnions, which allows a free tilting motion, as it is essential that the solutions be kept in constant motion during the process. A strip of paraffined paper, about eight inches wide, is drawn tightly around the edge of the mirror, leaving about six inches above the mirror. This is tied tightly with a chord. Then the paper strip is cemented to the glass by running a hot soldering iron several times around on the outside of the paper, above and below the cord, and the overlapping ends of the paper band are cemented together in the same way. The Santiago mirror has a six-inch hole in the center; this was fitted with a wooden plug provided with a central opening and glass stopper. The plug was cemented lightly in the hole in the mirror with Rowland's "Universal" wax (four parts beeswax, one part Venetian turpentine, plus a little best English vermillion). A tight joint was made with a soldering-iron, as in the case of the paper band.

After cleaning with nitric acid, many advise following with a second swabbing with a solution of caustic potash followed in turn with an application of French chalk. I have secured better results with the nitric acid alone, and have not used the potash or chalk in recent years. On this point Common states: "With the most careful cleaning of a mirror, I have often found that the first application did not succeed, but the second on the surface just cleaned off with nitric acid was all right. The nature of the liquid other than distilled water last in contact with the surface of the mirror seems to be the determining thing." Dr. Common also preferred to silver face down when using Brashear's process, and used the Rochelle salts method when necessary to silver face up. He used a rather novel method to support the heavy mirror (37 inches in diameter; weight over four hundred pounds) when silvering face down. The back of this mirror was polished. A large cast-iron cell was made, 30 inches in diameter and about four inches deep; the edge was turned flat and true and then grooved; a large rubber washer was interposed between this cell and the mirror. From this cell or "sucker" the air was exhausted with a small air pump to a pressure of about five inches of mercury; the atmospheric pressure was then sufficient to hold the mirror to the "sucker" when face down or even when the mirror was placed in a vertical position. Considering the great weight of the glass, the method seems rather drastic. Professor Wright silvered the Santiago mirror (diameter 37¼ inches; weight 562 pounds) face down on several occasions, but supported the mirror in a ring with trunnions. This mirror and that of the Crossley have a semi-circular groove about one-half inch deep around the middle of the edge, forming a safe method for support by a holding ring.

SILVERING FORMULÆ—COMMON'S PROCESS.*

Quantity used for 250 square inches (1.613cm.^{2}) of mirror surface:

A. 1 oz. (31 g. †) silver nitrate.
10 oz. (300 cc.) water.
Clear up completely with ammonia.

B. 1 oz. (31 g.) caustic potash.
10 oz. (300 cc.) water.

* *English Mechanic*, 34, 464, 1882.

† In changing these formulae to the metric system, the quantities have occasionally been rounded off when it seemed evident that no error would arise thereby.

Pour into A and clear again with ammonia.
Add a weak reserve solution of silver nitrate, drop by drop, till the appearance is decidedly turbid again.

C. Reducing solution:
½ oz. (15 g.) glucose.
10 oz. (300 cc.) water.
Add C to the mixture of A and B, stirring well. "At a temperature of about 56° a fine film was got in 43 minutes on a three-foot mirror. I have used some of the same solutions at various times to silver small surfaces, and I find I can get a good film in much less time, particularly if the temperature is a little higher. No doubt, for higher temperatures some modifications would have to be made; but the use of glucose allows a more certain determination of the proportions proper for certain temperatures than any mixture of sugar and acid, the active properties of which, as a reducing agent, are uncertain and changeable."

MARTIN'S PROCESS.*

1. 175 grains (11.34 g.) silver nitrate.
10 oz. (300 cc.) water.
2. 262 grains (16.98 g.) nitrate of ammonia.
10 oz. (300 cc.) water.
3. 1 oz. (31 g.) caustic potash.
10 oz. (300 cc.) water.
4. Dissolve ½ oz. (15.55 g.) sugar candy in 5 oz. (150 cc.) water; add 52 grains (3.37 g.) tartaric acid; boil for ten minutes; when cool add 1 oz. (30 cc.) alcohol; make up mixture to 10 oz. (300 cc.) in winter and to 12 oz. (360 cc.) in summer.
Mix equal parts of 1 and 2; mix equal parts of 3 and 4 in another vessel; combine when ready to silver; immediately on changing color immerse the mirror.

ROCHELLE SALTS PROCESS (JAMES).†

1. Silvering solution:
48 grains (3.11 g.) silver nitrate.
1 oz. (30 cc) distilled or rain water.
Add ammonia slowly till brown precipitate is nearly but not quite re-dissolved. Filter, and add distilled water to make 12 fluid drachms (45 cc.).
2. Reducing solution:
12 grains (0.78 g.) Rochelle salts.
1 oz. (30 cc.) distilled or very clean rain water.
Boil in flask, and while boiling add 2 grains (0.13 g.) silver nitrate dissolved in one drachm water. Continue boiling five or six minutes; cool, filter, and add distilled water to make 12 fluid drachms (45. cc).
Take equal parts for silvering; temperature of 113° to 122° F. (45° to 50°C.) is best. When solution becomes clear, process is finished taking twenty to eighty minutes; if left in longer, bleaching begins.

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* *English Mechanic*, 30, 416, 1880.
† James quoted in *English Mechanic*, 28, 113, 1878.

METHOD USED BY DRAPER.

1. 337 grains (21.83 g.) nitrate of silver.
   10 oz. (300 cc.) water.
2. 1½ oz. (46 g.) caustic potash.
   25 oz. (750 cc.) water.
3. 1½ oz. (46 g.) milk sugar in powder, pure and fresh.
   10 oz. (300 cc.) water.
   Pour nearly all of 1 into a vessel that will hold 160 oz. (5 liters),—the quantities given are for a 28-inch (71.1 cm.) mirror; add ammonia drop by drop till the gray precipitate clears; add 20 oz. (600 cc) of 2, and with ammonia just re-dissolve the brown precipitate that forms. Make up to 75 oz. (2,250 cc.) with water, then add some of 1 till a gray precipitate that does not dissolve in three minutes is left. Then make up to 150 oz. (4,500 cc.) with water. Let it all settle, and pour off. When ready to immerse the mirror, add all of 3.

THE CROSSLEY PROCESS.

This was sent to the Lick Observatory by Mr. Gledhill. It was regarded as a trade secret at that time (about 1895). I find, however, that the essential part of the process was patented by Pratt in 1876, and is now generally known, forming a step in the method used by Mr. Lundin. There seems no longer, then, any reason why its publication should be withheld. The quantities are for a three-foot mirror.

No. 1 The silver solution:

Place 7½ oz (233 g) of nitrate of silver in a jug; pour on it 4½ oz. (135cc.) of ammonia (.880); stir till dissolved. Add 2½ pints (1,200cc.) of distilled water; stir well. Filter into clean glass bottle with glass stopper. Keep in a dark place; this will keep.

No. 2. The "salts" solution:

½ lb. (250 g) of Rochelle salt and ½ gallon (2.3 liters) of distilled water. Mix and shake till dissolved. Filter. This will keep.

No. 3. The "wash" solution:

Dissolve ½ lb. (250 g.) of crystals of protochloride of tin in 1 pint (480 cc.) of distilled water. A milky solution is obtained, with white sediment. Shake up before use. This will keep.

To prepare the solutions for silvering: For the wash take 2 drachms (7 cc.) of No. 3 and 12 pints (6 liters) distilled water. Mix well.

For the silvering solution: To each pint (liter) of distilled water add 1 oz. (64 cc.) of No. 1. and stir; then add 2 drachms (16 cc.) of No. 2 for each pint (liter) and stir.

In the use of this process all solutions should be somewhat warm. The mirror should also be warmed; this is accomplished by placing it in a large pan and pouring water into the pan a number of times, each time slightly warmer than the last, till a temperature of 100° to 120° F. (40° to 60° C.), is reached.

The mirror is now tilted and the water thrown off its surface; while tilted the jug of "wash" solution is poured on the surface at the uppermost point so that a stream of the solution runs down and wets the whole of the surface. The mirror (still tilted) has now two or three eight or ten-pint jugs of warm distilled water poured over it, no parts being missed. It is then quickly levelled and about twelve pints (six liters) of the prepared silver solution are poured upon it. If the mirror be warm enough the silver will be seen on the glass here and there in one or two minutes.

When the solution becomes discolored pour some fresh solution on (in the middle, or where any bare place is seen). Continue in this way till the coating is deemed thick enough. Then tilt mirror to throw off the discolored solution; throw over the surface a few quarts of warm distilled water; wipe surface all over with a handful of cotton wool, and tilt into a vertical position to drain and dry.

This process is said to give a very good coat; I have personally seen no example of a fresh coat obtained in this way from which to judge as to its excellence and thickness, and the only trial of the method I have made (on a small mirror) gave very indifferent results, doubtless through lack of experience. When the Crossley mirror was shipped to the United States in 1895, the silver coat was found in excellent condition when the box was opened at Mt. Hamilton (silvered by the above process?). This particular coat was later used for all Director Keeler's nebular photography, and the mirror was not resilvered till about January, 1902. It is evident from this that the coat must have been one of unusual durability and excellence.

The function of the chloride of tin wash in this process and that used by Mr. Lundin is obscure. It seems essential that only the merest trace of the chloride shall be left when the silvering solutions are poured on. Quincke found that the slightest trace of chlorine would seriously impair the silvering process; he states that a millionth part of common salt in the silvering fluid is sufficient to make the resulting coat unfit for polishing, and advises that when only small amounts of solution are being used great care should be taken to prevent the natural perspiration of the hands from injuring the mixture.

BÖTTGER'S METHOD.*

1. Dissolve 5 grams silver nitrate in distilled water; add ammonia till the precipitate almost entirely disappears; filter and dilute to a volume of 500 cc.

* Kohlrausch, Leitfaden der prakt Physik, 207.

2. Dissolve 1 gram of silver nitrate in a little water and pour into 500 cc. boiling water. Add to this 0.83 gram Rochelle salt, and let the mixture boil for a short time until the deposit appears gray. Filter while hot. The solutions will keep for several months in a dark place. After cleaning the glass, pour over it equal volumes of the two solutions. The process is complete after one hour, and may be repeated to secure a greater thickness of film. The operation can be quickened by warming the *second* of the two solutions given above to 70° C. before mixing the two. Best results secured from silvering face down.

BRASHEAR'S PROCESS.*

The Reducing Solution:

This should be made up in advance; the older it is the better it will work. If necessary to use a freshly made reducing solution, the action may be improved by boiling it, adding the alcohol after it has cooled. The formula is as follows:

Rock candy 90 grams.
Strong nitric acid (spec. gr. 1.22), 4cc.
Alcohol, 175 cc.
Distilled water, 1,000 cc.

The Silvering Solution:

(The quantities are as used for the Crossley mirror.)

A. 3 liters distilled water.
250 grams silver nitrate.
Strongest ammonia, as may be needed.
B. 1 liter distilled water.
125 grams caustic potash (purified by alcohol).
C. 25 grams silver nitrate.
200 cc. distilled water. Reserve solution.

In solution A, after the silver nitrate is all dissolved, add ammonia gradually; the solution at once turns dark brown. Keep on adding ammonia, in quite small quantities toward the close till the solution just clears up; avoid an excess of ammonia. Then pour in solution B. The mixture will again turn dark brown or black. Again slowly add ammonia, as before, till the solution just clears. The solution should now be a light brown or straw color, but transparent.

Now add as much of the reserve solution, C, as the mixture will take up without turning too dark; add this reserve solution rather slowly, stirring constantly. If 25 grams is not enough, add more, for it is important that the nitrate be as much in excess as is possible. It is best to add this reserve solution till there is quite a little brown suspended matter which the solution refuses to take up. Filter through absorbent cotton to remove these suspended particles.

* *Astrophysical Journal*, 1, 252, 1895.

Operations should be performed at a temperature of 55° to 73° F. (17° to 23° C.). If the solutions are much warmer than this, the resulting coat may be very soft, and there is, moreover, danger of the formation of some light gray silver fulminate, very explosive. Dr. Brashear uses ice to keep the temperature below 70° F. in warm weather. If the solutions are too cold, it will be difficult to secure a coat of sufficient thickness.

Clean several drinking glasses or beakers with nitric acid, rinsing with distilled water. Make several tests of the completed solution, taking of the reducing solution one fifth or one fourth of the quantity of silvering solution employed. Note approximately the time required to get a thick coat and what proportions of reducing solution works best. Too much reducing solution gives a black dirty coat. I generally find that about 800 cc. of reducing solution is best for the amounts given above for the Crossley mirror, and that the process is completed in from five to ten minutes.

The mirror, fitted with a band of paper as described earlier, and cleaned, has about four liters of distilled water standing upon it. Pour 800 ± cc. of reducing solution into the silvering solution, and pour at once into the water already on the mirror. Keep the solution in motion by rocking the mirror, but avoid letting any part of the mirror be exposed to the air for longer than a second or two to observe progress.

The great trouble with the Brashear process is the formation of much sediment, and the solution should be kept constantly in rapid motion so that this sediment does not remain long in any one spot. For this reason some have preferred to silver face down. Dr. Common on one occasion very successfully silvered his five-foot mirror face up by this process, omitting the potash, when the silver was deposited from a nearly clear liquid, leaving no mud on the surface. This procedure, however, has been very uncertain, in my hands, and the coat thin. For avoiding the sediment I find the following procedure better: Two persons provided with rubber gloves, stand on opposite sides of the mirror, and each has, on a clean sheet of paper within easy reach, four or five good-sized handfuls of absorbent cotton About one minute after the solution is poured on, and as soon as a bright coat begins to form, each person takes a handful of the cotton and swabs his half of the mirror very rapidly, but very lightly. No pressure is exerted, but the wet cotton is allowed to move over the surface with only its own weight. *Every* part of the mirror must be touched by the

cotton. By this process the solution is kept in rapid motion, and most of the sediment is taken up by the cotton. Every half minute or so the used cotton is slightly squeezed, thrown away, and a fresh handful taken.

A difficult point is the decision as to when the process should be stopped. If the solution is thrown off too soon, the coat will be thin; if left on too long, a whitish bleach deposits, and no amount of burnishing will make such a bleached coat as brilliant as one correctly deposited. One may be guided by the time taken for the preliminary tests made on beakers, or tilt the solution slightly to one side and look through from beneath at a window or other opening. A thick coat is better in every way, particularly from its ability to stand repeated burnishings.

When completed, get the spent solution off as quickly as possible, tear off the paper strip, dash with ordinary water and then with distilled; swab the surface lightly with wet absorbent cotton if there is much "bloom" on the surface (I generally omit this); turn on edge to dry. After an hour the coat is ready for burnishing.

LUNDIN'S METHOD.*

The mirror is cleaned in the usual way with nitric acid. After the nitric acid has been rinsed from the mirror, the surface is then ready to receive a thorough rubbing with a saturated solution of tin chloride, which can best be done by making up a large wad of cotton, and holding the same in the hand so that the fingers cannot come in contact with the glass surface.

To test the surface for freedom from grease spots, etc., rinse off the tin chloride solution, rubbing the surface all the time; first with the same wad of cotton, and lastly with one or two clean wads. This will prevent the tin chloride from leaving a hard, thin film, which might otherwise form on the surface and give a granular appearance to the silver coat.

If the cleaning has been properly done, the surface after rinsing should not shed water as does a greasy surface, but should be able to retain a film of water over the entire surface when slightly inclined, and care should be taken to keep the entire surface covered with water; otherwise the silver will not deposit properly on those parts that have been exposed to the air.

* Extracts from a letter from Mr. C. A. R. Lundin Jr., of Alvan Clark and Sons, to the writer.

A dish is formed with the mirror as bottom by wrapping tightly around the edge a strip of bandage cloth three inches in width that has previously been saturated with melted beeswax, and carefully pulled while hot from the beeswax between metal rods to remove the excess of wax which would otherwise prevent a water-tight contact with the edge of the mirror. The rim of waxed cloth can be held sufficiently tight to the edge of the mirror by a few turns of strong string and, after tying securely, wetting the same.

Having completed the above preparation, attention may be turned to preparing the silvering and reducing solutions, at the same time occasionally pouring off the water from the mirror and replacing it with a fresh supply. The total amount of solution required for silvering can now be ascertained by measuring the amount of rinsing water that it takes to cover the surface in its highest part by about three quarters of an inch.

> Silver solution: Dissolve 10 grains (2.16 g.) of silver nitrate for each ounce (100 cc.) of silver solution used; add strong ammonia and clear up fully.
>
> Reducing solution: 20 minims (4 cc.) of Merck's formaldehyde in five times its volume of water for each ounce (100 cc.) of silver solution used.

The solutions having been prepared, the water covering the mirror is now poured off, the silver and the reducing solutions are mixed quickly but thoroughly and poured into the mirror as evenly as possible. Rock the dish slowly in different directions and watch for the appearance of black grains similar to gunpowder. When the solution is clear with the exception of these particles and they seem to deposit on the silver coat, pour off the solution and rinse with running water. Remove the waxed band, all the time keeping the surface flooded with water. The remaining particles and the dull-looking deposit on the silver may now be removed with a clean wad of cotton, trailed over the wet surface without pressure.

The advantages of this process are the practically complete freedom from the troublesome sediment of the Brashear process and the possibility of using ordinary water instead of distilled. Mr. Lundin states that the water from the mains at Cambridge is equal to distilled water for the purpose, and would advise others to test their water supply on a small mirror before securing distilled water. The water for the clean-

ing should be lukewarm, and a trifle less for the solutions; should the silvering solution turn a muddy brown color when poured on the mirror, the temperature of the mirror is too high. Dr. Parkhurst writes that he finds the Lundin process more convenient and reliable than the Brashear or the Rochelle salt method. In his opinion, the most important step appears to be the rinsing off of the chloride of tin with warm water, as all traces of the chloride must be removed to give a good film.

To be Continued

AN INQUIRY INTO A CERTAIN APPLICATION OF THE THEORY OF PROBABILITIES.

THOMAS BIRD DIXCY.

In his "Researches on the Evolution of the Stellar Systems," Dr. T. J. J. See has propounded in the Capture Theory a doctrine that, emanating from such an authority, must, perforce, occasion great and immediate interest among physicists and scientists in general and astronomers in particular; and which will, without doubt, be received with wide divergences of opinion. It is not the purpose of this paper to discuss that theory. Indeed, the writer is quite unqualified to do so. He is without scientific attainments and makes no claim to any greater mathematical ability than is necessary to enable him, with pleasure to himself, to "sit at the feet of Gamaliel" and profit from those labors of others which do not lead him into depths of learning too profound.

Dr. See has abridged his "Theory" in a series of papers in the *Astronomische Nachrichten*, some of which have been republished in POPULAR ASTRONOMY. In the issue of this publication for March, 1910, (No. 173), there appears the tenth and final article on the "Origin of the Lunar Terrestrial System by Capture;" closing with a "summary and conclusions" comprising sixteen numbered propositions controverting the theory of the detachment of the Moon from our planet. With the last thirteen of these this paper is not concerned. The query indicated in the caption is directed toward the first three, which undertake to prove, by an application of the theory of probabilities,

that the detachment of the Moon is so improbable and "the chances against it so overwhelming, as to wholly exclude it from consideration."

From a casual, or even moderately attentive, perusal of the argument presented, it would appear to be convincing. So convincing, in fact, as to be conclusive. If it is a proper and logical application of the theory of probabilities it *is* conclusive, and additional arguments are redundant. Careful examination, however, indicates that it is fallacious; analysis demonstrates it to be so.

Passing Dr. See's propositions (1) and (2) which are merely introductory, let us examine number (3), which contains the essence of his argument. Dr. See here predicates his contentions upon the hypothesis that the Sun's satellites and the satellites of those satellites "could originate in but one of two possible ways; namely: by capture, and (or) by detachment, and that the likelihood of either is equal in the case of each. Next, he shows that there are 693 of these bodies besides our Moon and, having previously examined each separately and found all except the Moon to have been "certainly captured," he argues that since this is so, when by the doctrine of chances it was a reasonable expectation to find that about half of them had been detached, then the odds in favor of the capture of the Moon, also, are so overwhelmingly great as to place the alternative beyond possibility. These odds, Dr. See says, are at least $(2)^{693}$ to unity; and he expands this symbol into a number exceeding a decillion decillion times a decillion decillion times a decillion decilions: a stupendous quantity, any single factor of which is absolutely beyond comprehension and leaves conception stunned. But though the result arrived at numbs the imagination, the method of determining it is elementary.

It can readily be shown that the probability of one of two events occuring for a specific number of consecutive times is the continued product of the separate chances that it may happen each time; not the sum of such chances. In general, the probability of the occurrence of n favorable events out of m possible chances for r consecutive times may be expressed $\left(\frac{n}{m}\right)^r$ and the odds against it may be stated as $m^r - n^r$ to n^r.

Thus, it is apparent that from a box containing one white and one red billiard ball, either may be drawn; and that, the drawer being blindfolded, the chances of each are equal and may be expressed as $\frac{1}{2}$. The chance of drawing the white ball

twice in succession is not, however, ½ plus ½; but ½ multiplied by ½, or ¼, and the chances are said to be three to one against it; for it is obvious that the balls may be drawn in four ways, only one of which will satisfy the conditions. They may be drawn: (1) white, and again white; or (2) White, Red; or (3) Red, White; or (4) Red, Red; the balls, of course, being replaced in the box each time. In like manner, the probability of drawing the white ball three consecutive times is ½ times ½ times ½, or ⅛, for the balls may be drawn as follows:

(1) W. W. W. or (5) R. W. W. or
(2) W. W. R. or (6) R. W. R. or
(3) W. R. W. or (7) R. R. W. or
(4) W. R. R. or (8) R. R. R.

or seven chances *against* drawing the white each time, to one in favor of it. The illustration might be extended indefinitely.

It is by the application of this principle that Dr. See arrives at the conclusion that the chances against the detachment of the Moon are $(2)^{693}$ to unity; and our inquiry is for the purpose of determining whether his conclusion is logical and warranted by the theory of probabilities and the facts.

We are first led to ask why, if Dr. See could independently prove the capture of 693 other bodies of our solar system, he could not, by the same methods and formulae, prove the capture of the Moon as well, without finding in necessary to rely upon "probability?" Was it because the surrounding conditions were so intrinsically different that our satellite would not yield to the mathematical processes employed in the other instances? Sir George Darwin, by his exhaustive researches, was induced to believe that the lunar-terrestrial phenomena would be found to be absolutely unique within our system, and in this he has been supported by many astronomers of international reputation. Miss Clerke in her "History of Astronomy" says that "Professor Darwin's first researches on this subject were communicated to the Royal Society, December 18, 1879. They were followed, January 20, 1881, by an inquiry on the same principles into the earlier condition of the entire solar system. The results were a warning against hasty generalization. They showed that the lunar-terrestrial system, far from being a pattern for their development, was a singular exception among the bodies swayed by the Sun. Its peculiarity resides in the fact that the Moon is *proportionately* by far the most massive attendant upon any known planet. Its disturbing power over

its primary is thus abnormally great, and tidal friction has, in consequence, played a predominant part in bringing their mutual relations into their present state.

"The comparatively late birth of the Moon tends to ratify this inference. The dimensions of the Earth did not differ (according to our present authority) very greatly from what they now are when her solitary offspring came, somehow, into existence. This is found not to have been the case with any other of the planets. It is unlikely that the satellites of Jupiter, Saturn, or Mars (we may safely add, of Uranus or Neptune) ever revolved in much narrower orbits than those they now traverse; it is practically certain that they did not, like our Moon, originate very near the *present* surfaces of their primaries."

Now, it must be borne in mind that however small the *probability* of an occurrence, it never precludes the *possibility*. The improbability may be so overwhelmingly great that the possibility of the event would be beyond human comprehension. As the improbability approaches the infinite, the probability approaches the infinitesimal; but it *never disappears*. The improbability may be characterized by all the superlative adjectives in the unabridged dictionary; but the probability still remains. It *can* happen and it *may* happen. That "the unexpected is sure to happen" is more than an epigram; it is true, *given enough trials*. Within the writers experience there is a case in point. He numbers among his friends a certain trained nurse whose specialty is obstetrics. She is so skilful and her professional and personal reputation is so high that her services are eagerly sought and, to this writing, she has officiated at the birth of 84 Young Americans. Just half of these have been boys, but the utterly astounding fact is that the *sexes have alternated*; the "odd numbers" all being boys and the "evens," girls. The chances against such a sequence, while not to be compared with Dr. See's total, are sufficiently great to place the occurrence among the bewildering improbabilities. They are (barring mechanical errors in computation)

19,342,803,007,346,902,975,851,791 to 1.

Over nineteen septillions to one! It is not improbable that such a sequence has not been duplicated in the experience of any other one person in the existence of the human race. If it were possible for these children to have been the offspring of the same parents, physicians and other men of science would be justified in looking for the cause, the *law* underlying such a

happening; but since that was not, as in the nature of things it could not have been, the case, it can be ascribed to nothing but pure chance. Nevertheless, for some years past, this nurse has taken a mischievous pleasure in confidently and correctly predicting, to the chagrin and irritation of some of the doctors concerned, the sex of the expected heir.

The object here has been to show that even with the improbability of the Moon's detachment as great as Dr. See declares it to be, yet it *could* have occurred. In fact, under the same conditions, somewhere among the infinite number of solar systems in the existence of which many believe and none can deny, by the very theory of probabilities which Dr. See invokes, it is *bound* to occur, if a matter of chance alone, not once only but many times; and it is as likely to have occurred within *our* system as within any other.

But it is now urged that Dr. See's argument is based upon a fundamental error when he contends that the proof of capture of 693 "companion" bodies creates a presumption in the ratio of $(2)^{693}$ to 1 that the Moon, too, was captured.

Let us suppose that a coin be tossed for 693 consecutive times. The number of ways it may fall, taken all together, are the many decillions calculated by Dr. See. Obviously, it is as likely to fall in any one of these ways as in any other. It is true that the probability that it will fall in *any sequence specified beforehand* approaches the infinitesimal; but we have seen that it *may*; it *is possible* for it to do so. Suppose that the coin *has* fallen Heads for 693 consecutive times. Our only present interest in this improbability is *its influence on the result of the next toss.* Dr. See argues, in effect, that *because* this improbability *has* occurred, an improbability *twice as great* is bound to occur and that it *must* fall Heads for 694 times. Is this sound? The mind repudiates it at once! Past events of *pure chance* have clearly no possible influence on similar events in the future. The undeniable fact is that, notwithstanding what may have happened before, the coin is exactly as likely to fall Tails on the 694th. throw as to fall Heads. Indeed, through the "maturity of chances" due to the belief that "luck *must* turn," gamblers would argue that it is *more* likely and that the likelihood increases with each throw; but this contention cannot be supported by mathematical analysis.

Take a case more nearly analogous to Dr. See's. Suppose a curved, solid fence too high to see over, supported by 694 posts on the outside of the curve; and so constructed that the curve

cuts off the view from each post to all beyond. Suppose a man starts from the first post, which is painted white, and walks to the 693rd post; finding, as he comes to each, that it, too, is painted white. What are the chances that the 694th post is white? Are they decillions upon decillions to one? Assuredly not. A strong presumption has been created that it will be found to be white: one would be astonished, and it would be the occasion of curiosity and comment, to find it *not* white; but it may have been painted any other color whatever, either by accident or *by design*.

If Dr. See could first have shown the phenomena surrounding the Moon to be identical, or even similar, to those of all the other "companions," and stated that fact among his premises, he could then have argued that since the 693 other bodies were proved to have been captured, *chance* was practically eliminated *in their case* by the substitution of unvarying *law*; and that since the circumstances relating to the existence of the Moon were practically the same, it might fairly be accepted as proven beyond a reasonable doubt that its birth was in obedience to the same law. Such, however, is not his expressed contention and the writer does not understand that it can be assumed. The heavy preponderance of evidence to date is against the contention that primeval conditions were the same, as we have seen in Miss Clerke's condensation of Darwin's conclusions, supported as they are by the nearly unanimous endorsement of other eminent authorities. We could seem to be justified in answering in the affirmative our previous query and saying that it *was* precisely because he himself found the conditions surrounding the Moon to be so intrinsically different from those found anywhere else in our solar system, that Dr. See was driven to an illogical application of the theory of probabilities. This theory may be used with confidence in supporting an *a priori* argument; it fails in one *a posteori* such as Dr. See's. That a given cause is likely to produce a certain effect may be true; but it is not necessarily true that such effect can only be due to that specific cause, even though it has been so produced innumerable times before. That 2 plus 2 plus 2 are 6 is a certainty; but that 6 can be produced only by adding three 2's is a manifest absurdity.

Moreover, it is possible to refute Dr. See's contention by using his own argument and even emphasizing it. At the time he wrote, there were 660 known asteroids: there are now 701. Thus we have 8 principal planets, 701 asteroids, and

about 425 comets; *all revolving around the Sun in the same direction.* Therefore, that *all* bodies revolve around the Sun in the same direction, the chances must be $(2)^{1184}$ to unity; a number so far transcending Dr. See's result that comparison is futile. The fact is, however, that, say, 400 comets (notably among them our own "Halley's" of recent memory) revolve in a *retrograde* direction. It may be protested that the conditions are not similar: that comets are admittedly *sui generis*; that they are not proven to be of the Sun's family at all; and that the conditions may be and probably are entirely dissimilar. The same objection adheres to Dr. See's argument.

If *all* his bodies revolved around the *Earth* the theory upon which he places so great a reliance might be more directly applicable; but who shall say that any phenomenon, except those due to the seemingly fundamental law of gravitation, prevails anywhere else in the universe; even among those bodies so closely allied to us as to be dominated or influenced by our Sun. Indeed, the vagaries of the Moon are such as to have caused no less a man than Simon Newcomb to suggest that even *that* law might be found subject to revision.

Yet another illustration; not, however, open to the same criticism. Seven hundred asteroids revolve around the Sun in the same direction and *in the same general plane* with a mean inclination to the ecliptic of about six degrees. Shall we say, then, that by odds greater than Dr. See's $[(2)^{700}$ to 1], *all* asteroids must revolve practically in that plane? "Pallas," with an orbit inclined at nearly 35 degrees, confute us!

What, then, may reasonably be inferred from this part of Dr. See's argument? No more than this: that if all the other "companions" have indeed been proved to have been captured, a strong presumption may have been created that the Moon has been chptured likewise; but to this presumption it would be difficult, if not impossible, to assign a definite mathematical value; certainly, 693 to 1 would be the maximum.

That the Moon has been captured, the writer does not and cannot deny; but the theory of Probabilities is surely a poor crutch upon which to support that contention.

30 Church Street,
New York City.
May 6, 1911.

THE RIEFLER CLOCK SYSTEM OF THE CINCINNATI OBSERVATORY.

ELLIOTT SMITH.

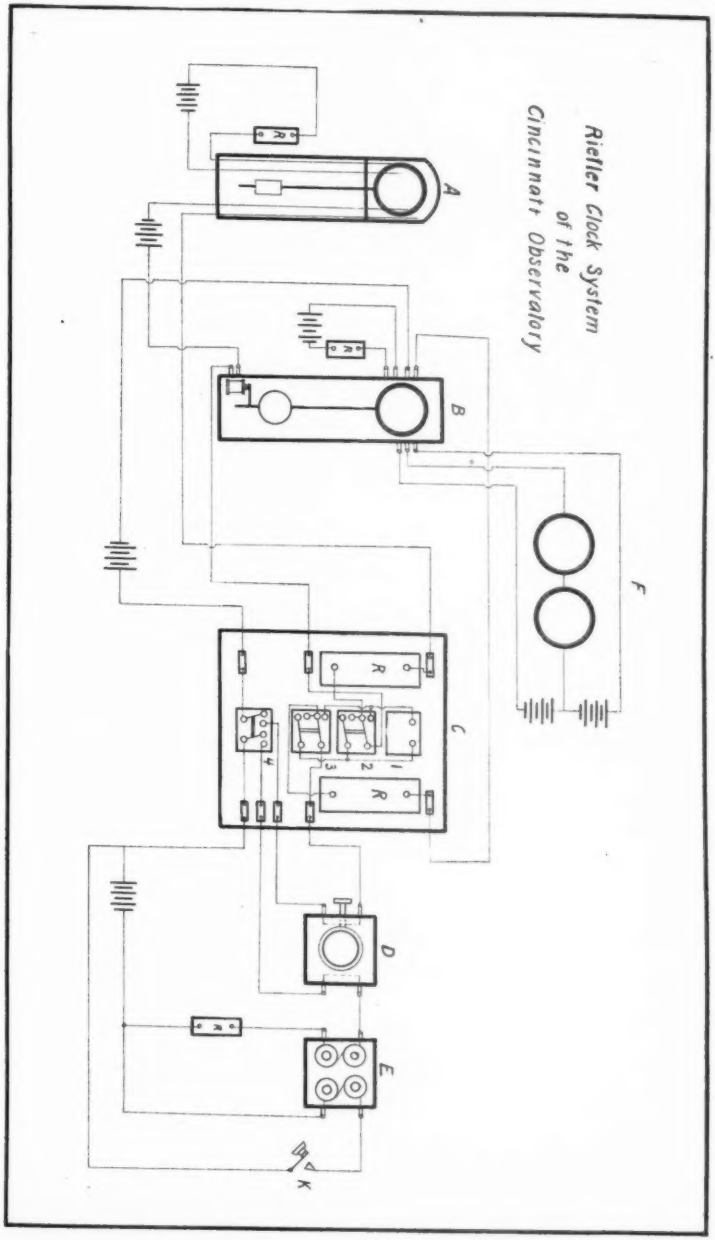
One of the chief requirements of an astronomer doing meridian circle work is an accurate clock. When one realizes that an uncertainty of one or two hundredths of a second of time in the rate of the clock may have an appreciable effect upon the observations its importance in this work of precision can be appreciated.

Director J. G. Porter has recently had installed at the Cincinnati Observatory one of the best systems of clocks available for astronomical work. Since it has been my duty to install these clocks under the director's supervision, I take this opportunity of giving to readers of POPULAR ASTRONOMY a description of the clock system and a discussion of its behavior for the past year.

The clocks were made in Germany by Clemens Riefler and are known as Riefler clocks. The system as installed at the Cincinnati Observatory is shown in the accompanying figure. A represents the standard or control clock, B the secondary clock, F the electric secondary clocks, C the switchboard, D the relay, E the chronograph and the R's resistance coils. The fine lines represent battery circuits and the reader will have little difficulty in tracing them and understanding their purpose.

The battery circuits to the left of each of the clocks A and B serve to wind them. They are wound about every thirty-five seconds. The electric secondary clocks, F, as the name implies are run by electricity. A current alternated each second by the secondary clock B is sent through them causing the second hand of each to move forward one division on its dial. Thus if the hands of the electric secondary clocks are set the same as those of B the time as given by all of them thereafter will be the same. One of these electric secondary clocks is in the meridian circle room, the other in the dome of the 16-inch telescope.

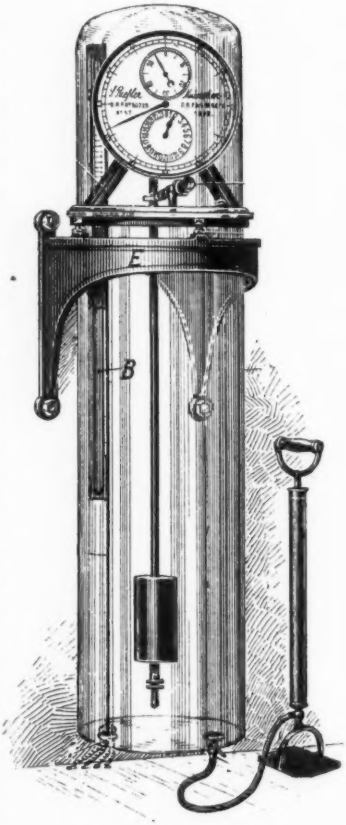
A circuit from clock A connected with the switchboard runs to the electromagnet under the pendulum of clock B. Clock A closes this circuit one second, makes it an open circuit the following second and this alternately closed and open circuit


Riefler Clock System
of the
Cincinnati Observatory
A
B
C
D
E
F
K
R
R
R
1
2
3
4

serves to give clock B exactly the same rate as A. It is technically called the circuit of synchronization. The only work imposed upon clock A is to control clock B.

A break circuit from clock B connected with the switchboard operates the relay D in the circuit of the chronograph E. The observations are recorded by the key K. Referring to the switchboard, C.1 is a milli-ampère-meter, C.4 serves to close the chronograph and relay circuits, C.3 to throw the milli-ampère-meter into the relay circuit, and C.2 to throw it into the circuit of synchronization.

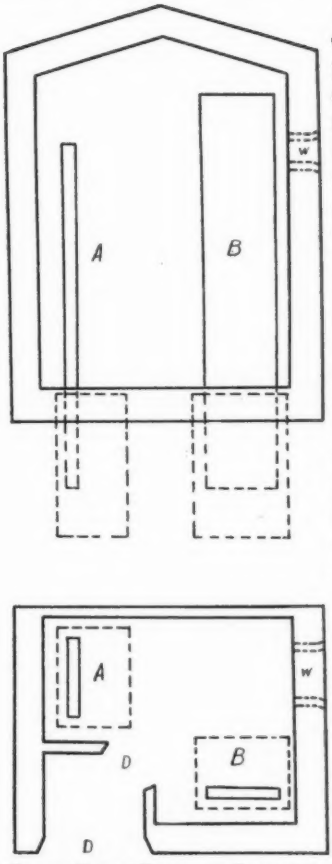
The most important and valuable part of this equipment is the standard or control clock. Without giving a detailed description I may say that three of the several features which distinguish it from others are (1) the nickel-steel compensation of the pendulum, (2) the free escapement of the pendulum, no part of the clockwork being connected with it below the point of oscillation, and (3) the air tight glass case in which the clock-work is inclosed admitting of an air-pressure compensation of the pendulum.



THE RIEFLER CLOCK.

Air may be pumped out of the case as desired by a pump provided for this purpose and a barometer within shows the decrease in pressure. It is known that a decrease in air pressure within the case accelerates the clock $0.^{s}018$ per millimeter decrease in barometer reading and a 100 mm. decrease produces an acceleration of $1^{s}.8$.

When a volume of inclosed air undergoes a decrease in temperature a decrease in pressure within the inclosed space results. It was to be expected therefore that a change in temperature of the air within the clock case



CLOCK VAULT PLAN AND ELEVATION.

would produce a very marked change in its rate. Contrary to prediction one of the most interesting things brought out in the following discussion of rates is the fact that the clock rate is nearly compensated for change of pressure produced by change in temperature.

For the work at this observatory it was not deemed necessary to provide a constant temperature apparatus for the clock vault. The object sought was prevention of sudden changes in temperature. The plan and elevation of the vault are shown in the accompanying figure. The floor space is 4 ft. x 6 ft. The walls are made of a double thick. ness of hollow tile laid in cement and finished inside and out with a cement surface. The inner surface is covered with heavy paper and to this has been added a layer of woolen felt.

The piers are marble slabs set in beds of cement under the floor of the vault. Holes were drilled in these slabs and the clock cases bolted to them, the standard or control clock being mounted on the pier marked A. Its dial can be seen and the thermometer and barometer read by an observer looking through the window W, and hence when the clocks are mounted and running properly there is no necessity for opening the vault. A set of double doors prevents a sudden change of temperature within when it is necessary to enter the vault.

The clocks were mounted early in the summer of 1909 and after a short time it was noted that there was a slight leak in the case of the standard clock. No little difficulty was experienced in locating this leak. I finally found it to be just below the ground glass rim upon which the bell-jar covering

the clockwork rests. A little pocket of wax softened with vaseline was pasted to the case at this point and filled with fluid water-glass, the point at which the leak occurred being completely submerged and covered. The leak was stopped at once by the fluid and later a glazed surface was formed over it making the mend permanent. The clock was finally sealed in January 1910 and after some changes in barometric pressure was left to run undisturbed after March 1.

TABLE OF VAULT TEMPERATURES.

Month	Mean	Max.	Min.
	°	°	°
1910 Feb.	10.3	11.0	8.2
March	13.4	17.5	11.2
April	15.9	17.5	14.0
May	15.7	17.0	14.2
June	17.8	21.0	15.0
July	21.9	22.2	21.0
Aug.	22.0	23.0	21.0
Sept.	21.2	22.0	20.0
Oct.	18.4	21.0	14.8
Nov.	14.1	15.0	11.7
Dec.	8.9	11.0	7.5
1911 Jan.	8.6	11.2	7.4
Means	15.7	17.4	13.8

In the accompanying table are given the mean, maximum and minimum temperatures for each month throughout the year.

In the tables of rates the clock corrections are taken directly from observing programs carried out in connection with my regular meridian circle work. No observations were made for the one purpose of determining clock correction and rate and where observations were made on consecutive dates the clock correction determined on one of them has been omitted, the criterion for rejection being the equalization of the time interval between the dates of the preceding and following clock corrections used. All others are included.

Each barometer reading given in the table is the mean barometric pressure for the period from which the corresponding rate is derived. Changes in barometric pressure, except where noted, are produced by a change in temperature.

In Table I the residuals were derived from the means of consecutive clock rates where these rates seem to have been constant for the corresponding interval of time; their significance is slight and they might have been omitted from the table. The column of rates, however, contains data that are very interesting and suggestive.

TABLE OF RATES. I.

Date	Bar.	Tem.	Corr.	Rate	Res.	
	mm.	°	s	s	s	
1910, Mar. 2	698	10.4	− 2.541			
" 4	701	11.6	− 2.387	+0.077	−0.016	
" 7	704	13.0	− 1.971	+ .139	+ .046	
" 12	705	12.2	− 1.800	+ .034	− .059	Residuals
" 15	704	12.0	− 1.687	+ .038	− .055	from the
" 21	706	12.7	− 1.091	+ .099	+ .006	mean rate
" 25	708	14.1	− 0.655	+ .109	+ .016	+0s.093.
April 1	715	16.5	+ 0.377	+ .147	+ .054	
" 7	720	17.0	+ 0.899	+ .087	− .006	
" 9	719	16.9	+ 1.113	+ .107	+ .014	
" 27	715	15.6	+ 1.069	− .003	+ .002	
May 5	715	16.5	+ 1.160	+ .011	+ .016	
" 10	715	15.7	+ 1.128	− 006	− .001	Residuals
" 13	716	16.0	+ 1.155	+ .009	+ .014	from the
" 18	713	14.7	+ 0.861	− .059	− .054	mean rate
" 25	715	16.0	+ 0.883	+ .003	+ .008	− 0s.005.
" 28	717	17.0	+ 0.976	+ .031	+ .036	
June 1	717	17.0	+ 0.775	− .050	− .045	
" 6	716	15.9	+ 0 885	+ .022	+ .027	
" 7	---	---	---	---	---	Clock A drops 60.s
" 14	668	16.0	+55.365			Pressure changed.
" 16	668	16.0	+54.158	− .604	+ .001	
" 23	676	18.0	+49.412	− .607	− .002	Residuals
" 28	683	21.0	+46.999	− .583	+ .022	from the
July 13	686	21.8	+38.069	− .595	+ .010	mean rate
" 18	688	22.0	+34.881	− .638	− .033	−0s.605.
Aug. 12	688	22.0	+15.426	− .778		
" 15	688	22.0	+12.833	− .864		
" 19	---	---	--.	---	---	Pressure changed.
" 19	716	22.0	+ 9.803			Residuals
" 26	716	22.0	+ 7 378	− .376	+ .014	from the
" 28	715	21.6	+ 6.490	− .404	− .014	mean rate
						−0s.390.
" 30	---	---	---	---	---	Pressure changed.
" 30	715	21.6	+ 5.842			Residuals
Sept. 9	736	22.0	+ 5.349	− .049	+ .041	from the
" 16	734	21.5	+ 4.593	− .108	− .018	mean rate
" 27	733	21.0	+ 3.235	− .112	− .022	−0s.090
" 28	---	---	---	---	---	Clock stopped
Oct. 8	720	19.0	+15.564			
" 11	718	18.5	+16.625	+ .354		
" 13	---	---	---	---	---	Pressure set at 700 m.m.

Although the barometric pressure increases from 701 to 720 between March 4 and April 7 there is no indication of a change in the clock rate. If air were admitted increasing the pressure by this amount we would expect the rate +0s.077 given for March 4 to become +0s.420. In fact between March 2 and June 6 the table shows that the rate experienced a negative acceleration where a positive might have been expected.

On June 7 the standard clock was stopped one minute and the barometric pressure decreased 48 mm. We would expect this decrease to change the rate $+0^s.022$, as given for June 6, to $-0^s.842$. An inspection of the table shows that the rate became $-0^s.604$ and that it required until August 15 for the predicted rate to be realized. On August 19 air was admitted to the case increasing the pressure 28mm. and predicted rate $-0^s.360$ corresponded almost exactly to the rate actually derived for the interval between August 19 and August 26. Air was admitted again on August 30 increasing the pressure 21mm. and again predicted and observed rate were in accord.

The standard clock stopped September 28 and it was necessary to open the case in order to start it. It was then found that the secondary clock had a rate of $+0^s.50$. In 1909 when it was started it was given a rate of $-1^s.00$ before synchronization. It is probable that at that time it had not assumed its normal rate and the change suggests the desirability of occasionally switching the electro magnet under the pendulum of the secondary clock out of the synchronizing circuit and rating it.

If the normal rate of the secondary clock was $+0^s.50$ for the whole period between March 2 and September 28, it was necessary for the synchronizing current to perform a very perceptible amount of work in order to produce the rates recorded in Table I. If we assume that the secondary clock reacted upon the standard clock tending to decrease its rate the anomalous results above noted are easily explained. The tendency was toward the normal rate of the standard clock, undoubtedly, but it required time for the standard clock through the synchronizing circuit to impart this rate to the secondary clock. The performance of the clocks when the pressure was decreased by pumping air out of the case as compared with its performance when it was increased by admitting air verifies this supposition.

A "$1^s.0$" weight was added to the pendulum shelf of the secondary clock October 8 giving it a rate of $-0^s.50$ and the two clocks were synchronized. The barometric pressure within the case was adjusted to the reading 700mm., October 13 and has not since been changed.

In the table of rates II the residuals are from the mean of clock rates derived between October 22, 1910 and April 1, 1911. Employing the residuals a solution was made on the assumption of a Δ rate with change of barometric pressure

TABLE OF RATES, II.

Date	Bar.	Tem.	Corr.	Rate	Res.	Corr.Res.
	mm.	°	s	s	s	s
1910 Oct. 22	703	19.0	+17.727			
" 26	700	17.1	+17.685	−0.010	+0.103	+0.017
Nov. 4	694	15.6	+17.170	− .057	+ .056	− .004
" 7	689	14 3	+16.956	− .071	+ .042	+ .003
" 12	688	13.6	+48.541*	− .083	+ .030	− .004
" 20	683	12.0	+47.589	− .119	− .006	+ .007
" 25	682	11.9	+47.041	− .110	+ .003	− .006
Dec: 7	680	11.1	+45.328	− .143	− .030	− .030
" 14	674	9.0	+44.148	− .168	− .055	− .029
" 17	672	8.3	+43.877	− .090	+ .023	+ .057
1911 Jan. 6	671	8.2	+40.417	− .173	− .060	− .021
" 22	674	9.4	+38.471	− .122	− .009	− .016
" 30	676	10.0	+37.512	− .120	− .007	+ .010
Feb. 1	678	11.2	+37.220	− .146	− .033	− .024
" 9	677	10.5	+36.494	− .091	+ .022	+ .034
" 15	677	10.0	+35.449	− .174	− .061	− .048
" 22	680	11.0	+34 898	− .079	+ .034	+ .034
" 27	674	10.0	+34.083	− .163	− .050	− .024
Mar. 14	676	10.6	+32.200	− .126	− .013	+ .004
" 20	679	11.6	+31.527	− .112	+ .001	+ .005
" 24	681	12.0	+31.043	− .121	− .008	− .012
April 1	680	11.4	+30.237	− .101	+ .012	+ .012
Means	680	11.7		−0.113	±0.032	±0.019

Δ rate = + 0ˢ.0043 per 1 m.m.

when this change was produced by a change in temperature. The solution gives, Δ rate = + 0ˢ.0043 per mm., and the column of corrected residuals was derived by applying it to the residuals of the preceding column. This Δ rate is equivalent to a temperature rate-coefficient of about 0ˢ.010 per degree Fahrenheit and 0ˢ.018 per degree Centigrade. For the ordinary astronomical clock this is considered small and it is a source of gratification to know that it is no larger for this Riefler clock mounted as it is.

The system of clocks has given satisfaction and as installed meets fully the requirements of this observatory.

* Clocks drop 32ˢ

THE GYROSCOPE AS A COMPASS.

HYLAND C. KIRK.

If after considering the peculiar effects of gravity on the gyroscope in its common form, and also upon the spinning top, the belief should remain that such effects are due to an attraction in matter, this idea ought consistently to be dispelled when the actions of the former instrument are observed as substituted for the compass to determine latitude.

That every rotating wheel or disc tends, when free to do so, to maintain unaltered the plane of its rotation, is true—with a single qualification; and to this qualifying circumstance the investigator, seeking to understand the true character of gravitation, should direct his attention.

"It is with a curious mixture of feeling," says John Perry,* "that one first recognizes the fact that all rotating bodies, flywheels of steam-engines and the like, are always tending to turn themselves towards the pole star. "The spinning axis of the Earth, which we have to regard as controlled largely by the same forces determining its cohesion, gyration, and revolution around the Sun, points very nearly to the pole star; and this peculiarity of a free gyrating body to turn its axis in the same direction as the axis of the Earth, is the strongest kind of evidence that attraction has little or nothing to do with the phenomena usually attributed to gravitation, but that all such rotating bodies, alike with the Earth, are controlled and their movements directed by a force or forces from the outside to turn their axes in this particular direction. For whether the free-moving disc is set moving with its axis tangent or perpendicular to the Earth, in either of which positions it would tend to be maintained, naturally and equally, if gravity were a pull from below, it actually shifts its position in opposition to such a supposed force, and turns its axis toward the pole star.

An account of this striking phenomenon is given by Professor James Blyth in the Encyclopaedia Brittanica, article, Gyroscope:

"If the gyroscope have all degrees of free rotation round a point, and be in every way exactly balanced about that point, and also have all its pivots nearly void of friction, then, at

* Spinning Tops, p. 108.

whatever part of the Earth's surface it may be placed, the fly-wheel while rotating rapidly will be observed to move gradually and finally to take up such a position that its axis is parallel to the Earth's axis, and also that its direction of rotation is the same as that of the Earth round its axis."

The experiment has been tried by different investigators in different parts of the Earth and with uniform results, while the various actions of the instrument as related to latitude, longitude and time, have been computed mathematically and found in agreement with the Earth's movement. If seven different instruments were located at as many different points on

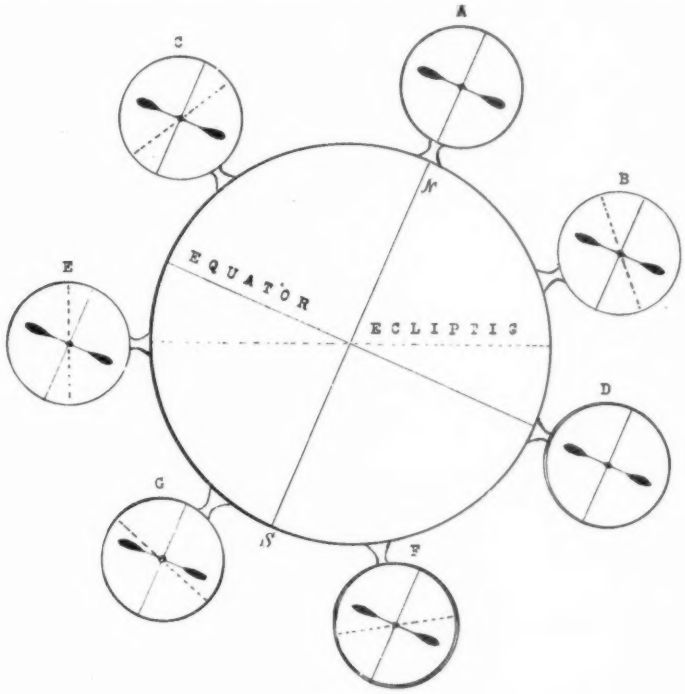


FIGURE 1.

the Earth as shown in figure 1, we may suppose that the discs would all rotate in the same direction, corresponding to the rotation of the Earth, and in planes parallel to each other and the equator, with their axes parallel to each other and the Earth's axis. If a graduated scale marking degrees were at-

tached to each, so as to indicate variations of the axis from a tangent to the Earth, we should find them indicating degrees of latitude in the following order: A, at the north pole, 90°; B, 45°; C, 25°; D, at the equator 0°; E, at the ecliptic, 23½°; F, 60°; and G, 70° south. Accordingly it will be seen that this form of the gyroscope may be used in place of the compass to indicate direction, latitude, longitude, show the rotation of the Earth, and illustrate various other phenomena.

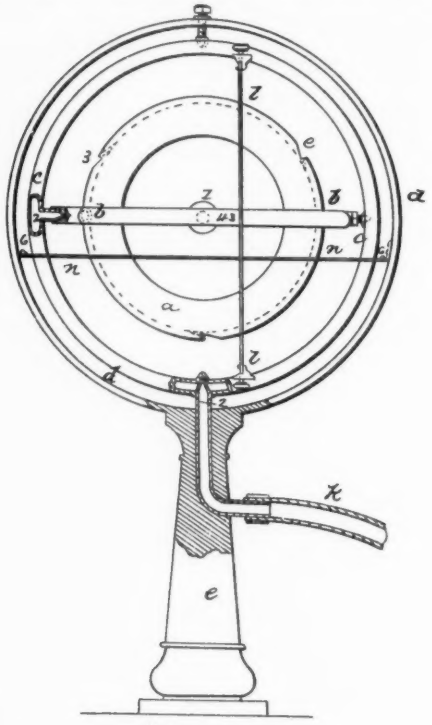


FIGURE 2.

A considerable number of inventions have been made of this character, seeking to substitute the work of the gyroscope for that of the compass. Letters Patent were issued as early as February 4, 1862, to Benjamin Garvey of Ashland New York, on an "Improvement in ascertaining position and direction on land and sea," the original application being dated New York, October 26, 1857. This invention was practically a gyroscope of the type now being considered, which the inventor designed;

to render the rotation of the Earth visible and to measure time; to measure changes in latitude; to measure changes in longitude; to indicate the horizontal direction of a course; to indicate the direction of the course in a vertical plane; and to determine the course and position of the apparatus as it is moved from place to place. The disc of Mr. Garvey's gyroscope which he called a "Leveling Instrument," had a hollow shaft and circular chambers with vents in the rim, and was propelled by forcing air or steam through, on the principle of Barker's mill (Figure 2). Graduated circles and indicators being suitably attached, the rotation of the Earth was made

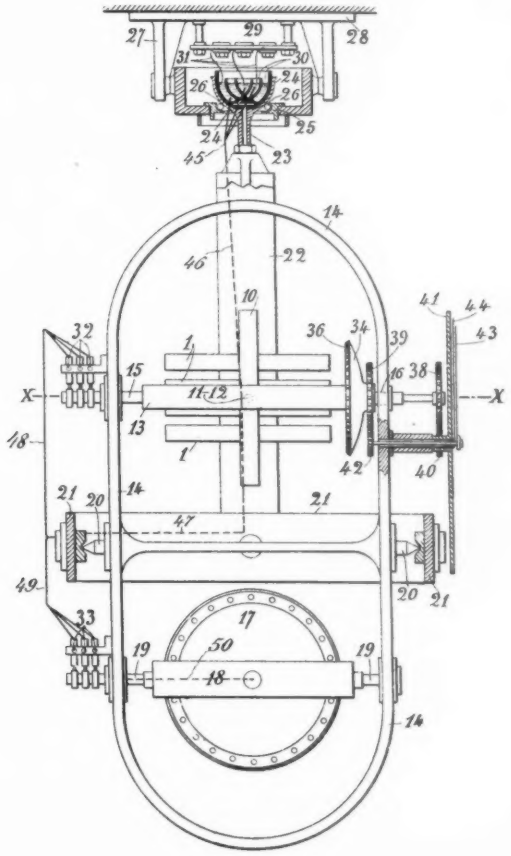


FIGURE 3.

visible by simply setting the disc in motion, the varying angle between the Earth's movement and that of the instrument being shown on the scale; changes in latitude were indicated when the fly-wheel was set rotating in the plane of the equator the angle indicating the latitude, and changes in longitude by causing the disc to rotate in the plane of the meridian, differences in time being taken into account.

In 1882 a patent was granted by the Prussian Government to Charles de Nottbeck of St. Petersburg, Russia, on a "Gyroscope for determining geographical location on the Earth without the Sun or compass observations." This consists of a gyroscopic disc mounted in a metallic semi-circle, the central arm of which hangs from a pivoted shaft, thus affording three directions of movement to the disc, the latter being driven by electric currents.

In 1907 a patent was issued by the United States Government to Filippo Vanzini, an officer in the Italian army, on a nautical apparatus consisting of a "freely suspended and rapidly rotating gyroscope" (Figure 3), designed as a substitute for, and to supplement the work of the ordinary compass; and the same year patents were issued to J. D. Stannard of Arizona, on "a nautical indicating device by which the course of a vessel may be indicated on a globe or map and the position of the vessel at any time in its course or location on the Earth's surface determined with approximate accuracy without the necessity of making the usual observations and calculations, the object of the invention being to provide a device of this character which will be sufficiently accurate for all practical purposes and of value in cloudy and stormy weather and at other times when observations cannot be made" (Figure 4).

We are not informed as to the practical outcome of the Stannard invention, but it deserves success on the ground of utility as well as ingenuity of construction. Experts of the United States Navy disagree as to the merits of the gyroscopic compass chiefly because of the mechanical difficulties involved though Rear Admiral Cowles, chief of the naval bureau of equipment, believes it has now reached a stage where it is a valuable adjunct to the magnetic compass.

An invention on which Letters Patent were granted by the United States Government in 1905 to Herman Anschutz-Kaempfe of Kiel, Germany, a gyroscope "for use on ships as a substitute for, or as a means of corroborating or correcting the magnetic compass," appears to have been used quite success-

fully. This instrument involves two discs rotating parallel to each other, the upper part of the common shaft holding the frame of the discs being supported on a float, so as to afford free movement and thus preserve their planes of motion (Figure 5). The inventor says: "According to the well-known laws of the motion of the gyroscope, the spinning bodies

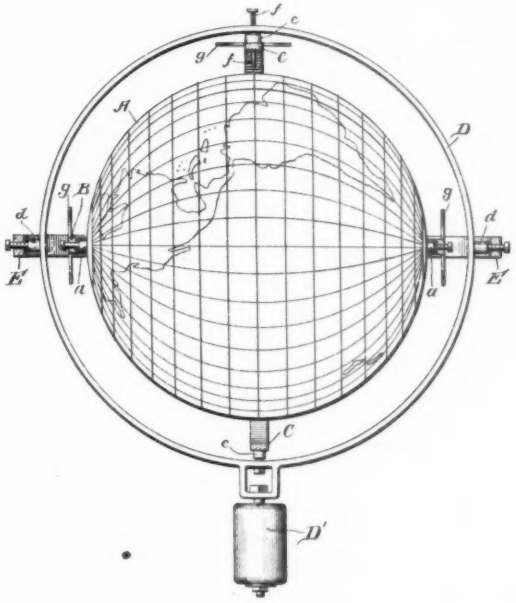


FIGURE 4.

of such an apparatus when they are once in a state of rotation have the tendency to retain the once assumed direction of their axis in space. The axial direction can consequently be regarded as a fixed line of direction, by which, for example a ship can be steered accurately, as when a compass is employed. The device behaves like Foucault's pendulum, and consequently does not participate in the rotation of the Earth about its axis, but on the contrary, exhibits a motion relative to the Earth."

The first to utilize this instrument in a definite way to demonstrate the rotation of the Earth, Foucault, in 1852, made use of a single heavy disc, the frame of which was suspended by a thread, and supported by a pivot at its base resting in

an agate cup. The determination of any change in the elevation of the plane in space in which the axis of the disc rotated being the chief purpose of the experiment, the disc delicately pivoted in the ring was set rapidly rotating by a separate machine, and suspended by knife edges in slots of the frame. A graduated scale on the suspended frame, and a telescope bearing upon this scale, completed the arrangements.

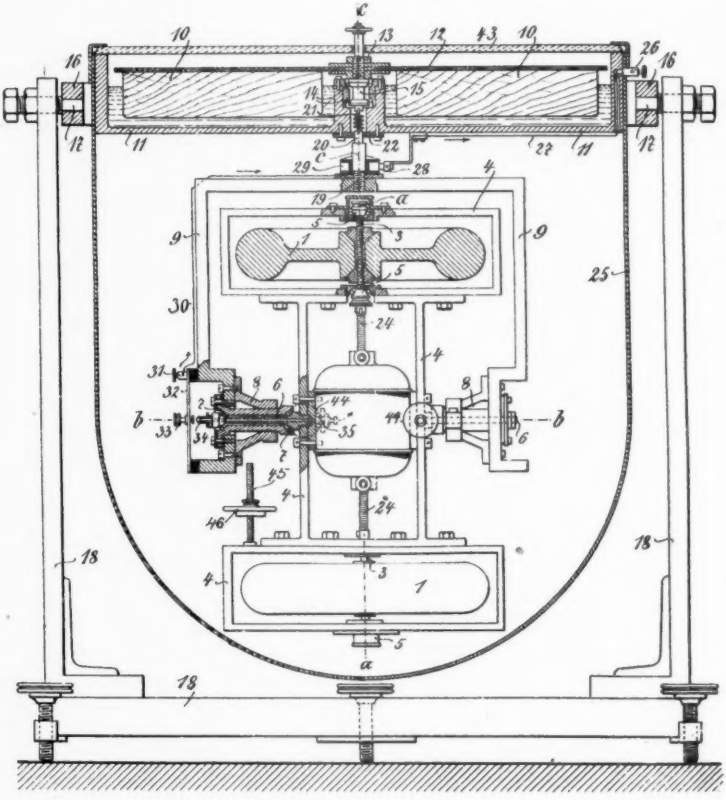


FIGURE 5.

Foucault's instrument seems to have been so accurately constructed and poised that its axis must have responded very quickly to the influence effecting the Earth's gyration—pulling it into line with the Earth's axis—whence its apparent deviation from the fixed plane proved the rotation of the Earth.

Some fifteen years previously Poinsot* had set forth the proposition that "each molecule of a moving body is animated by a force equal to its mass into its velocity," the basis of Foucault's principle as to fixity in the plane of rotation, while the question as to whether the axis of his gyroscope was made to coincide with the projection of the parallel to the Earth's axis, is set at rest by Foucault's own words. His report, which was read before and filed with the editor of the Academy, in view of the claims of "another savant," may be translated as follows:

Meeting of October 4, 1852.

Experimental Demonstration of the Movement of the Earth. An Addition to Communications made in Preceding Sessions by M. Foucault.

Having completed during the month of May last all my experiments to demonstrate the movement of the Earth by means of the rotation of bodies, I have been constrained to secure for myself the right of property, to give the results in a letter and to announce them outside of the Academy. As this document has been discussed in this body and considered insufficient to assure me the priority (of discovery), I beg of the Academy permission to lay it before them and to beg them to authorize its insertion in the reports.

(Extracts from the Journal of Debates, September 22, 1852).

Monsieur le Redacteur,

Permit me to communicate to you some new results of experiments which I have been making for some time, and which furnish some additional physical proofs of the movement of the Earth.

In seeking to discover some new evidences of this grand phenomenon, I have taken the fixity of plane of a body which rotates, as I had formerly done with the plane of oscillation of the pendulum.

It had appeared to me that a body turning about a principal axis and freely suspended by its center of gravity, ought, just the same as the pendulum in swinging, to resist the influence of the rotation of the globe. An apparatus which I had constructed for this purpose has in fact given a new proof of the movement of the Earth which I sought.

Steadily rising in absolute space, the axis of the gyrating body seems to retrograde slowly from the east to the west, and to move continuously in the field of the instrument

* (Liouville's Journal, First Series, Vol. 16.)

like the image of a celestial body in the focus of an astronomical lens.

I had often noticed, in the experiment of bodies turning upon themselves, a singular property which reason had anticipated beforehand; I mean a force of orientation which tends to direct the axis of the body parallel to that of the Earth, and to dispose the two rotations in the same way. This rising force always manifests itself when the axis of the rotating body is put in a fixed plane with that of the Earth, at the same time conserving the liberty to maintain itself in this plane.

This new property of revolving bodies gives very apparent evidence of the movement of the Earth, and resembles up to a certain point evolutions of the magnetic needle.

If it works in a horizontal plane the axis of the body directs itself toward the north and the apparatus functions in the same manner as an ordinary compass; if it is worked in a vertical plane, the axis of rotation inclines and represents, in approaching the direction of the Earth's axis, the needle which works in the inclined compass.

After four months trial all these facts are to my mind settled beyond a doubt, and in communicating them to the Academy of Science, I quietly awaited the expiration of the vacation and the return of a time more favorable for the presentation of quite a long work. But having learned that a very honorable savant was about engaging himself in the direction of my pursuits, I thought it my duty, moreover, without delaying a single day, to lay definitely and particularly before you and before the public, the facts acquired by my efforts in this branch of science.

It may be interesting at this point to examine the claims of this "other savant" and determine just what credit he is entitled to, in connection with the application of the gyroscope to the demonstration of the Earth's rotation. In the "Proceedings of the Society for the Encouragement of Useful Arts in Scotland" for March 9, 1836, is reported as the third communication, "Suggestions of a New Experiment whereby the Rotation of the Earth may be demonstrated," by Edward Sang, Esq., Vice President Society of Arts. M. Foucault's experiments in Paris and before the British Association at Liverpool, coming to the attention of the Scottish society, Mr. Sang's paper was recalled, and re-read by that gentleman before the Society March 24, 1856; in which this language occurs:

Only one experiment, purely terrestrial, has yet been contrived, which demonstrates, without the intervention of astronomical considerations, the fact of the Earth's rotation on its axis. That is the experiment of dropping a heavy body from a great height and contrasting the direction of its motion with that of a plumb-line. But this experiment, on account of the small deviation, can only be made in peculiar situations where a great fall can be obtained. The deep shafts of the coal-mines in the neighborhood of New Castle afford the only opportunity in this district of verifying by such a trial the important fact of the Earth's rotation.

The oblateness of the Earth is only known by measurements partly astronomical, and thus could never have led to the knowledge of the rotation of our planet had the stars been concealed from us.

While using Troughton's top, an idea occurred to me that a similar principle might be applied to the exhibition of the rotation of the Earth. Conceive a large flat wheel, poised on several axes, all passing exactly through its center of gravity; and whose axis of motion is coincident with its principal axis of permanent rotation, to be put in very rapid motion. The direction of this axis would then remain unchanged. But the direction of all surrounding objects varying on account of the motion of the Earth, it would result, that the revolving wheel would appear to move slowly.

Were the influence of friction and the air's resistance suspended, the axis would appear to perform a circuit daily; it would in fact describe the surface of a cone, of which the polar line would be the axis; and were a telescope placed along it, that telescope would point always to the same fixed star. It would indeed be an equatorial telescope.

The remainder of Mr. Sang's paper is devoted to discussing the difficulty of obviating friction in order to attain success in this experiment. Before reading his paper at this time, he had stated that with one exception, the phenomena disclosed by and attributed to M. Foucault's experiments, had been previously exhibited and explained many years before by Sir John Leslie, "not as at all new, but as well known and well understood results of the acknowledged laws of mechanics;" the exception referring to the motion of the Earth—a circumstance which led to the preparation of his own contribution. At the

close he stated that the great expense involved in securing accuracy had prevented him from making the actual experiment, and he ended his essay as follows:

> In thus claiming the priority by some 18 years, I have not the slightest wish to detract from the merits of M. Foucault in regard to this experiment; my interest indeed would rather lie in the exaltation of these merits. Many an invention has been re-invented—many a discovery again discovered; and amidst the multitude of contrivances which surround us, it is a mere fiction to suppose that an explorer is bound to avoid every field that has been explored before. My object is simply to place myself—and I may be allowed to add—to place this Society—rightly in regard to the matter

In the discussion following, Professor Piazzi Smith scored the British Government for not having supplied funds to Mr. Sang for experimental purposes, as the French Government had done in the case of M. Foucault; and it may have been this very paper which induced Professor Smith, very soon afterwards, to devote considerable time to experiment along a kindred line. Professor C. Piazzi Smith was Astronomer Royal of Scotland at this time, and his experiments were in connection with a free-revolving stand for a telescope used at sea on the yacht "Titania", during a voyage to Teneriffe in the summer of 1856. The telescope was a small one magnifying but seven times, and having an eye-hole of one-eighth of an inch. The revolver was one foot in diameter, weighed ten pounds, and was driven by two sets of fly-wheels, one acting on either side of the spindle.

The apparatus was arranged inside a sort of observatory box located on the after deck, into which box the observer could insert his head and two hands, while openings for observation could also be made. The sailors worked the drive-wheels with their hands, and they did this with so much zeal it appeared that on one occasion they twisted the steel driving axle in two and thus prevented an observation of an eclipse of one of Jupiter's satellites. As to the working of the stand, Professor Smith reported that "having brought the horizon of the sea into the field of view, I was delighted to find it remained there, absolutely uninfluenced by rolling and pitching of the yacht."

That the force inducing the axis of the gyroscope to parallel itself to the Earth's axis has not been observed in many cases, as in that of Professor Smith's telescope-stand, and that its

character when noticed has not been given much thought, as in the cases of M. Foucault and M. Sang, does not affect the fact. The experiments of Mr. Sang and M. Foucault were directed toward the solution of another question, the rotation of the Earth; and so it has happened in many cases since that this action of the instrument, as illustrating the true character of gravitation, has, so far as records show, never been remarked or noted. And while there is still room for experimentation, it seems to be a fair inference from the facts so far as known, that the axis of the gyroscope parallels itself to that of the Earth, not by reason of any force contained within or drawing it toward the latter, but through some outside influence affecting Earth and instrument alike.

THE COMPUTATION OF THE TIMES OF RISING AND SETTING OF THE MOON. ADDENDUM.

ALBERT S. FLINT.

Since the publication of the article in the May number of POPULAR ASTRONOMY, a request for the time of rising of the upper and lower limbs of the Moon for a certain date at Madison has suggested a more general treatment of the device by which the required hour angle for the Moon may be derived from a table of hour angles on the horizon for the Sun.

In discussing the equation for $\cos t$ we had the substitution of $\pi - r$ for $r + s$ and hence derived the fictitious parallax $\pi = 2r + s$. If we put

$$z = 90° + \Delta z = 90° + (r + s), \quad \text{for the Sun}$$
$$z' = 90° + \Delta z' = 90° + (r' - \pi \pm s'), \quad \text{for the Moon,}$$

where r', π, and s' are the true or adopted values of the horizontal refraction, parallax, and semi-diameter for the Moon, respectively, it is seen that the substitution we make is $-\Delta z'$ for Δz, or that we put

$$\pi_i = \Delta z + r' \pm s';$$

where π_i is the fictitious parallax which corresponds to this substitution and where the upper or lower sign of s' applies according as the position is to be with the upper or lower limb on the horizon. The case for the center of the Moon is repre-

sented, of course, by simply putting $s' = o$. And since for a given latitude and declination, the hour angle depends solely upon the zenith distance of the body, we are not concerned how Δz may be distributed between r and s. Extreme values of the horizontal refraction at sea-level may be taken as about 47′.5 corresponding to a temperature of −20° F. and a pressure of 31.0 inches to about 28°.8 for a temperature of 100° F. and a pressure of 29.0 inches. The parallax of the Moon will be between 53′.9 and 61′.4 and the semi-diameter between 14′.8 and 16′.6. If we assume that the values of Δz adopted in the solar table was 52′, the extreme value of the fictitious parallax of the Moon are

$$\pi_f = 52'. + 47'.5 + 16'.6 = 116'.1,$$
$$\pi_f = 52\,. + 28\,.8 - 16\,.6 = \quad 64\,.2.$$

The first of these values occurs for the upper limb, the second for the lower limb.

For a second fictitious value of the parallax, we employ in a similar manner any other table of semi-diurnal arcs for the given station that may be available, or simply the equation

$$\cos\,(180° - t) = \tan\delta \tan\phi,$$

corresponding to which we have $\pi_f = r'$; so that the fictitious values of the parallax will always fall within reasonable limits, and it will only remain to interpolate between the corresponding hour angles in order to obtain the hour angle corresponding to the true parallax π.

It has been remarked that when a number of determinations may be required for a given station (latitude) it would be of advantage to compute a table of hour angles with the parallax as one argument. As noted above, we have $z = 90° + \Delta z$ in the case of any object, and we are not concerned how Δz may be distributed between refraction, parallax, semi-diameter, or any other terms; consequently there is no particular reason for singling out any one term, like the parallax, for the argument. We may make our table then simply in zenith distance and declination. Extreme values of Δz and z at sea-level will be

$$\Delta z = 47'.5 - 53'.9 + 16'.6 = +\,10'.2, \qquad z = 90°\ 10'.2,$$
$$\Delta z = 28\,.8 - 61\,.4 - 16\,.6 = -\,49\,.2, \qquad z = 89\ \ 10\,.8.$$

The first of these values of z occurs for the upper limb, the second for the lower limb of the Moon. A table of hour-angles in two columns, one for zenith distance 89°, the other for zenith distance 90°, and for whole degrees in declination from

$-30°$ to $+30°$, will contain no inconvenient differences, for moderate latitudes, and will serve for the Sun, the Moon, or any other zodiacal body. The general equation for $\cos t$ may be employed here to special advantage. A considerable part of the computation may almost be read off from the logarithmic tables, and a considerable part once made can be utilized again for a corresponding part of the computation. The column for $90°$ zenith distance is very simply obtained in accordance with equation (4). All that remains to be done then, in any particular case, is to make a sufficiently close estimate or preliminary computation of the Greenwich Mean Time, look up the declination from the ephemeris, ascertain the value of the zenith distance as composed of the several items, refraction, parallax, semi-diameter, or other terms, interpolate the hour-angle from the table, and go on as already shown to obtain the required time of rising or setting.

I take this occasion to make the following emendations to the article in the May number.

The meaning will be clearer if the sentence following equation (3) read thus: "If from this equation we write that for $\cos (180° - t)$, substitute $\pi - r$ for $r + s$, and change the sign of δ we have"

The last sentence in the text on the fourth page, including the equation, should read as follows: "For values of the latitude or of the declination at or very near zero, the equations for $\cos t$ must be put in the form

$$\cos t = \frac{\cos z}{\cos \delta \cos \phi} - \tan \delta \tan \phi.$$

Near the top of the eleventh page, following the second sentence of the second paragraph, there may be inserted the following: "Having obtained the result by one method, it is of course, legitimate to employ the corresponding Greenwich Mean Time in order to look out the data for the solution by the other method; hence only one solution by the latter will be required."

A few typographical errors have been discovered.

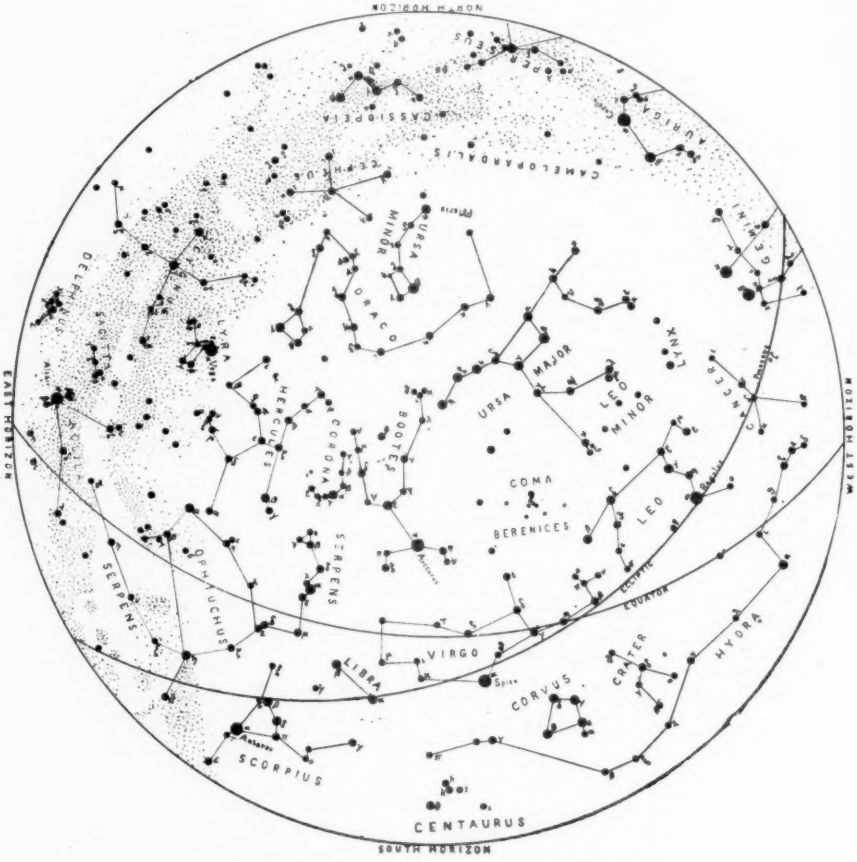
On the ninth page, in the middle of the thirteenth line from the bottom, the second t should have the accent, t'.

On the thirteenth and fourteenth pages, in the argument of the computation the item designated as (2) should read $\frac{1}{2}[z - (\phi - \delta)]$.

Washburn Observatory, Madison, Wisconsin.

PLANET NOTES FOR JULY AND AUGUST 1911.

Mercury will be at superior conjunction on July 3, and will be invisible for two or three weeks both before and after that date. It will reach its greatest elongation east of the Sun on August 12, on which date it will also be in



THE CONSTELLATIONS AT 9:00 P. M. JUNE 1, 1911.

aphelion. It will then be almost two hours east of the Sun in right ascension, but will be considerably south of the Sun, and will set at this latitude less than an hour after the Sun. It will possibly be visible low down in the twilight at this date.

Venus will continue to move east from the Sun until July 6 when it reaches its greatest elongation. It will then be very high in the sky at sunset and remain above the horizon nearly three hours after sunset. On this date Venus will be quite near the bright star Regulus. Venus will attain its greatest brilliancy on August 9, and will be at aphelion on August 19.

Mars will be in quadrature with the Sun on August 8. It will be 90° west of the Sun, and consequently will rise about midnight at that time and continue to rise earlier each succeeding night. Mars is approaching the Earth; on August 1 it will be about 100,000,000 miles away. The diameter of its disc increases about three seconds of arc during these two months.

Jupiter will be in quadrature with the Sun on July 29. It will be 90° east of the Sun and will therefore be on the meridian about sunset. It will be in a very favorable position for observation during these two months and will be a very interesting object in even the smallest telescope, because of the ever changing aspect of its satellites. During these months Jupiter will be receding from the Earth. The diameter of its disc will decrease about six seconds of arc during these two months.

Saturn will be 90° west of the Sun on August 13. About this time Saturn and Mars will be quite close together in the sky. Saturn will rise about midnight. It is approaching the Earth very slowly.

Uranus will be in opposition on July 20 and will cross the meridian at midnight. It will be rather low in the southern sky, being 21° south of the equator.

Neptune will be in conjunction with the Sun on July 14. It will consequently be invisible during the greater part of these two months.

Occultations visible at Washington.

Date 1911		Star's Name	Magnitude.	IMMERSION. Washington M.T. h	m	Angle f'm N. °	EMERSION. Washington M.T. h	m	Angle f'm N °	Duration h	m
July	7	22 Scorpii	4.8	12	7	56	13	7	322	1	0
	9	48 G Sagittarii	6.3	12	51	82	14	15	265	1	24
	12	86 B Capricorni	6.2	9	48	118	10	49	217	1	1
	13	143 B Capricorni	6.1	9	59	39	11	2	285	1	3
	13	154 B Capricorni	6.1	16	9	44	17	24	249	1	15
	15	ψ^3 Aquarii *	5.2	10	13	66	11	18	243	1	5
	18	o Piscium	4.4	13	0	46	14	0	249	1	0
	20	14 H′ Tauri	6.5	16	11	357	16	39	305	0	28
Aug.	3	41 G Scorpii †	6.3	11	14	73	12	20	304	1	5
	5	10 G Sagittarii	5.7	10	17	29	11	2	330	0	44
	8	40 B Capricorni*	6.2	6	38	120	7	36	226	0	58
	9	35 Capricorni	6.0	8	21	103	9	28	221	1	7
	9	37 Capricorni	5.7	14	3	50	15	18	245	1	15
	10	56 Aquarii †	6.1	18	8	102	18	52	199	0	43
	11	ψ^1 Aquarii	4.5	17	18	36	18	22	254	1	4
	13	155 B Piscium	6.5	18	36	22	19	33	270	0	57
	17	62 Tauri	6.1	17	28	38	18	38	276	1	9

* Immersion below the horizon of Washington.

† Emersion below the horizon of Washington.

Phenomena of Jupiter's Satellites.

Central Standard Time.

1911	h	m				1911	h	m			
July 2	7	53	II	Sh.	Eg.	22	8	52	I	Tr.	In.
	9	21	III	Oc.	Dis.		10	9	I	Sh.	In.
	11	5	III	Oc.	Re.	23	9	28	I	Ec.	Re.
6	10	38	I	Tr.	In.	30	7	56	I	Oc.	Dis.
7	7	48	I	Oc.	Dis.	31	7	29	I	Tr.	Eg.
	11	5	II	Oc.	Dis.		7	31	III	Ec.	Re.
	11	10	I	Ec.	Re.		8	45	I	Sh.	Eg.
8	7	19	I	Tr.	Eg.	Aug. 1	8	5	II	Oc.	Dis.
	8	31	I	Sh.	Eg.	3	7	31	II	Sh.	Eg.
9	7	51	II	Sh.	In.	7	7	12	I	Tr.	In.
	8	4	II	Tr.	Eg.		8	28	I	Sh.	In.
	10	28	II	Sh.	Eg.	8	7	46	I	Ec.	Re.
13	8	1	III	Sh.	In.	10	7	30	II	Sh.	In.
	9	38	III	Sh.	Eg.		7	38	II	Tr.	Eg.
14	9	40	I	Oc.	Dis.	14	8	49	III	Oc.	Dis.
15	8	14	I	Sh.	In.	16	7	4	I	Sh.	Eg.
	9	12	I	Tr.	Eg.	17	7	38	II	Tr.	In.
	10	26	I	Sh.	Eg.	19	7	48	II	Ec.	Re
16	7	33	I	Ec.	Re.	22	8	14	I	Oc.	Dis.
	7	56	II	Tr.	In.	23	6	47	I	Sh.	In.
	10	26	II	Sh.	In.		7	48	I	Tr.	Eg.
	10	35	II	Tr.	Eg.	25	7	56	III	Sh.	In.
18	8	2	II	Ec.	Re.	30	7	34	I	Tr.	In.
20	8	38	III	Tr.	Eg.						

Note.—In., denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

COMET AND ASTEROID NOTES.

Ephemeris of (395) Delia.

1911	α h	α m	α s	δ °	δ ′	log r	log Δ
June 1	16	26	59	−22	51.6		
3		25	11	22	44.2	0.3927	0.1634
5		23	24	22	36.8		
7		21	39	22	29.3	0.3922	0.1641
9		19	55	22	21.8		
11		18	15	22	14.2	0.3917	0.1659
13		16	38	22	6.8		
15		15	4	21	59.4	0.3913	0.1690
17		13	35	21	52.1		
19	16	12	10	−21	45.0	0.3909	0.1731

A. N. 4492.

Ephemeris of Halley's Comet:—Twenty months after its discovery by Wolf in 1909, Halley's comet is still visible in a fairly large telescope. It is about 13.5 magnitude, very diffuse, and has no tail or nucleus, although it is a

little brighter in the center. The following ephemeris for June is taken from Professor Ebell's note in *A.N.* 4492.

1911		α			δ		log r	log Δ
		h	m	s	°	′		
June	1	9	47	47	−4	46.1	0.7251	0.7303
	3		48	1		41.0		
	5		48	18		36.3	0.7280	0.7385
	7		48	36		32.0		
	9		48	57		28.0	0.7310	0.7464
	11		49	20		24.4		
	13		49	45		21.1	0.7339	0.7541
	15		50	12		18.2		
	17		50	41		15.7	0.7368	0.7615
	19		51	11		13.4		
	21		51	43		11.5	0.7396	0.7686
	23		52	16		9.9		
	25		52	51		8.6	0.7424	0.7755
	27		53	28		7.6		
	29		54	6		6.9	0.7452	0.7822
July	1		54	45		6.5		
	3	9	55	25	−4	6.3	0.7480	0.7886

Ephemeris of Comet *b* Metcalf.

1911		α			δ		log r	log Δ	Mag.
		h	m	s	°	′			
June	1	8	53	37	+51	17.9	0.5501	0.6013	14.0
	3		54	10	50	50.6			
	5		54	47	50	23.9	0.5544	0.6104	14.1
	7		55	27	49	57.8			
	9		56	10	49	32.3	0.5585	0.6191	14.1
	11		56	56	49	7.4			
	13		57	45	48	43.1	0.5627	0.6274	14.2
	15		58	36	48	19.4			
	17	8	59	30	47	56.2	0.5668	0.6353	14.3
	19	9	0	24	47	33.6			
	21		1	21	47	11.5	0.5709	0.6428	14.3
	23		2	20	46	49.9			
	25		3	20	46	28.8	0.5749	0.6500	14.4
	27		4	21	46	8.1			
	29		5	24	45	48.0	0.5790	0.6567	14.4
July	1		6	28	45	28.3			
	3		7	32	45	9.1	0.5829	0.6630	14.5
	5		8	38	44	50.3			
	7		9	44	44	32.0	0.5868	0.6689	14.5
	9		10	51	44	14.1			
	11		11	58	43	56.6	0.5908	0.6744	14.6
	13		13	6	43	39.6			
	15		14	15	43	22.9	0.5946	0.6796	14.6
	17		15	24	43	6.6			
	19		16	33	42	50.7	0.5985	0.6844	14.7
	21		17	42	42	35.2			
	23		18	51	42	20.0	0.6022	0.6887	14.7
	25		20	0	42	5.3			
	27		21	10	41	50.9	0.6060	0.6928	14.7
	29		22	19	41	37.0			
	31	9	23	28	+41	23.4	0.6098	0.6964	14.8

VARIABLE STARS.

New Variable Star 15.1911 Virginis:—In *A. N.* 4495 Mr. A. Massinger of Heidelberg announces the discovery of a new variable star in Virginis, the position of which is

$$1911.0 \quad \alpha \quad 11^h\ 55^m\ 50^s.74 \qquad \delta \quad -9^\circ\ 42'\ 37''.5$$

The star was found on plates taken in the course of a search for minor planets, being about 9.5 magnitude on March 31, 1911. On two plates taken in March and April, 1894 the star was of the 12.8 magnitude, and seems to have been of the same magnitude on April 22, 1901. On March 22, 1902, and March 17, 1906 the magnitude was 12.5; on January 13, 1908 it was 12.0; and from March 31, 1911 to April 3 it has been 9.5. A further study of this star would probably be of interest.

New Variable Star 16.1911 Trianguli:—In *A. N.* 4495 Professor W. Ceraski announces the discovery by Mme. L. Ceraski of a new variable, the approximate position of which is

	α	δ
1855.0	$1^h\ 48^m\ 20^s$	$+33^\circ\ 18'$
1900.0	$1\ \ 50\ \ 57$	$+33\ \ 31$

The type is as yet undetermined but it is evident from 28 photographs of the region that the variation ranges between magnitudes 10.5 and 12.5.

New Elements of ST Ophiuchi:—*Laws Observatory Bulletin* No. 17 contains a research upon the variable ST Ophiuchi by Mr. Harlow Shapley. From a discussion of 293 observations, made on twenty-nine nights and involving ten maxima, Mr. Shapley derives the new elements

$$\text{Max.} = 2418159.661 + 0^d.4503604 \text{ E, G.M.T.}$$

The range of variation is from $10^m.85$ to $12.^m40$. The ascent from minimum to maximum takes less than sixty-five minutes, while for the descent a little more than five hours is required.

New Elements of RW Camelopardalis:—These elements are also published by Mr. Shapley in *Bulletin* No. 17 of Laws Observatory, being derived from a discussion of nearly 150 observations made at that observatory. They are

$$\text{Max.} = 2417857.4 + 16^d.402 \text{ E, G.M.T.}$$

The variation is continuous and ranges between $8^m.48$ and $8^m.93$.

Approximate Magnitudes of Variable Stars on May 1, 1911.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn
χ Androm.	0	10.8	+46	27	<12	R Leo. Min.	9	39.6	+34	58	10.5*d*
T Androm.		17.2	+26	26	8.0 *i*	R Leonis		42.2	+11	54	8.4 *i*
T Cassiop.		17.8	+55	14	9.2*d*	R Urs. Maj.	10	37.6	+69	18	10.6
Y Cephei		31.3	+79	48	12.2	W Leonis		48.4	+14	15	<1.38
U Cassiop.		40.8	+47	43	8.3	S Leonis	11	5.7	+ 6	0	10.6*i*
RV Cassiop.		47.1	+46	53	11.0*d*	R Comae Ber.		59.1	+19	20	12.1 *i*
W Cassiop.		49.0	+58	1	10.3	R Corvi	12	14.4	−18	42	11.1*d*
S Cassiop.	1	12.3	+72	5	<10	T Can. Ven.		25.2	+32	3	19.4*d*
RU Androm.		32.8	+38	10	9.8 *i*	Y Virginis		28.7	− 3	52	2.6*d*
Y Androm.		33.7	+38	50	<12	T Urs. Maj.		31.8	+60	2	<10
Z Cephei	2	12.8	+81	13	<13	R Virginis		33.4	+ 7	32	8 0
S Persei		15.7	+58	8	8.5	RS Urs. Maj.		34.4	+59	2	14.1
RR Persei		21.7	+50	49	10.6	S Urs. Maj.		39.6	+61	38	9.4*d*
RR Cephei		29.4	+80	42	<13	U Virginis		46.0	+ 6	6	9.7*d*
W Persei		43.2	+56	34	12.3*d*	T Urs.Min.	13	32.6	+73	56	10.7 *i*
U Arietis	3	5.5	+14	25	9.8 *d*	R Can. Ven.		44.6	+40	2	<10
X Ceti		14.3	− 1	26	11.4	U Urs. Min.	14	15.1	+67	15	9.3
Y Persei		20.9	+43	50	<11	S Bootis		19.5	+54	16	9.1
R Persei		23.7	+35	20	<11	V Bootis		25.7	+39	18	9.3
R Tauri	4	22.8	+ 9	56	11.1*d*	R Camelop.		25.1	+84	17	9.3*d*
W Tauri		22.2	+15	49	<11	R Bootis		32.8	+27	10	<10
S Tauri		23.7	+ 9	44	10.8	S Cor. Bor.	15	17.3	+31	44	8.4*d*
T Camelop.		30.4	+65	57	9.5*d*	R Cor. Bor.		44.4	+28	28	6.6
RX Tauri		32.8	+ 8	9	8.9	X Cor. Bor.		45.2	+36	35	10.5*d*
R Orionis		53.6	+ 7	59	10.6	V Cor. Bor.		46.0	+39	52	10 0
V Orionis	5	0.8	+ 3	58	<12	RU Herculis	16	6.0	+25	20	8.0 *i*
R Aurigae		9.2	+53	28	9.1 *i*	U Herculis		21.4	+19	7	<10
U Aurigae		35.6	+31	59	<11	SS Herculis		28.0	+ 7	3	11.7
SU Tauri		43.2	+19	2	10.2	W Herculis		31.7	+37	32	<10
Z Tauri		46.7	+15	46	13.0	R Urs. Min.		31.3	+72	28	9.5
U Orionis		49.9	+20	10	7.5	R Draconis		32.4	+66	58	<10
V Camelop.		49.4	+74	30	<14	S Herculis		47.4	+15	7	7.6
Z Aurigae		53.6	+53	18	9.7 *i*	RV Herculis		56.8	+31	22	<11
X Aurigae	6	4.4	+50	15	<12	R Ophiuchi	17	2.0	−15	58	7.0
V Aurigae		16.5	+47	45	10.6	T Herculis	18	5.3	+31	0	10.7
V Monoc.		17.7	− 2	9	11.6 *i*	W Lyrae		11.5	+36	38	9.0
U Lyncis		31.8	+59	57	15.2*d*	SV Draconis		31.2	+49	18	10.5
S Lyncis		35.9	+58	0	13.5	RY Lyrae		41.2	+34	34	<13
X Gemin.		40.7	+30	23	10.5 *i*	Z Lyrae		56.0	+34	49	<12
Y Monoc.		51.3	+11	22	11.6 *i*	V Lyrae	19	5.2	+29	30	11.9*d*
R Lyncis		53.0	+55	28	10.8*d*	S Lyrae		9.1	+25	50	14.0
V Can. Min.	7	1.5	+ 9	2	<14	U Draconis		9.9	+67	7	12.0*d*
R Gemin.		1.3	+22	52	<13	R Cygni		34.1	+49	58	<9
R Can. Min.		3.2	+10	11	10.8*d*	χ Cygni		46.7	+32	40	9.0 *i*
RR Monoc.		12.4	+ 1	17	<13	Z Cygni		58.6	+49	46	<9
V Gemin.		17.6	+13	17	<12	RS Cygni	20	9.8	+38	28	8.6 *i*
S Can. Min.		27.3	+ 8	32	7.9 *i*	R Delphini		10.1	+ 8	47	<11
T Can. Min.		28.4	+11	58	<13	U Cygni		16.5	+47	35	9.9*d*
S Gemin.		37.0	+23	41	<13	T Aquarii		44.7	− 5	31	7.7
U Puppis		56.1	−12	34	<11	R Vulpeculae		59.9	+23	26	<10
R Cancri	8	11.0	+12	2	9.0 *i*	X Cephei	21	3.6	+82	40	<12
V Cancri		16.0	+17	36	12.1*d*	R Equulei		8.4	+12	23	<13
RT Hydrae		24.7	− 5	59	9.8 *i*	T Cephei		8.2	68	5	8.2
U Cancri		30.0	+19	14	14.0	S Cephei		36.5	+78	10	10.1*d*
S Hydrae		48.4	+ 3	27	12.1*d*	Z Cassiop.	23	39.7	+56	2	11.0
T Hydrae		50.8	− 8	46	8.5*d*	RR Cassiop.		50.7	+53	8	<12
T Cancri		51.0	+20	14	9.7	R Cassiop.		53.3	+50	50	8.0*d*
W Cancri	9	4.0	+25	39	10.8*d*						

Approximate Magnitudes of Variable Stars on May 1, 1911—Con.

The letter *i* denotes that the light is increasing; the letter *d*, that the light is decreasing; the sign <, that the variable is fainter than the appended magnitude. The above magnitudes have been compiled by Mr. Leon Campbell of the Harvard College Observatory from observations made at the Amherst, Vassar, Mt. Holyoke, Olcott, Jacobs, Swartz, Hunter and Harvard, Observatories.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours, etc. For stars marked thus * alternate minima are given; ** every third minimum; † every tenth minimum.]

SY Androm.

d	h
July 9	18
Aug. 13	15

*U Cephei

d	h
July 4	23
9	22
14	22
19	22
24	21
29	21
Aug. 3	21
8	20
13	21
18	21
23	20
28	20

*Z Persei

d	h
July 4	1
10	4
16	6
22	9
28	12
Aug. 3	14
9	17
15	20
21	23
28	1

RY Persei

d	h
July 7	16
14	12
21	9
28	6
Aug. 4	3
10	23
17	20
24	17
31	14

**RZ Cassiop.

d	h
July 3	5
6	19
10	9
14	0
17	14
21	4
24	18
28	8
31	22

**RZ Cassiop

d	h
Aug. 4	12
8	2
11	16
15	6
18	20
22	10
26	0
29	14

*ST Persei

d	h
July 5	20
11	3
16	10
21	17
27	0
Aug. 1	8
6	15
11	22
17	5
22	12
27	19

RX Cephei

d	h
July 5	21
Aug. 7	5

*Algol

d	h
June 4	3
9	21
15	14
21	8
27	2
Aug. 1	19
7	13
13	6
19	0
24	18
30	11

**RT Persei

d	h
July 1	1
3	14
6	3
8	16
11	5
13	19
16	8
18	21
21	10

**RT Persei

d	h
July 23	23
26	12
29	2
31	15
Aug. 3	4
5	17
8	6
10	19
13	8
15	22
18	11
21	0
23	13
26	2
28	15
31	5

λ Tauri

d	h
July 3	23
7	22
11	21
15	19
19	18
23	17
27	16
31	15
Aug. 4	14
8	13
12	12
16	10
20	9
24	8
28	7

*RW Tauri

d	h
July 4	11
10	0
15	13
21	2
26	15
Aug. 1	4
6	17
11	5
16	18
22	7
28	20

*RV Persei

d	h
July 1	14
5	12
9	11
13	10
17	9
21	7
25	6
29	5
Aug. 2	4
6	2
10	1
14	0
17	22
21	21
25	20
29	19

RW Persei

d	h
July 8	4
21	9
Aug. 3	14
16	19
29	23

RS Cephei

d	h
July 9	1
21	11
Aug. 2	21
15	7
27	17

*RY Aurigae

d	h
July 5	23
11	10
16	21
22	8
27	19
Aug. 2	6
7	17
13	4
18	15
24	2
29	12

*RZ Aurigæ

d	h
July 1	16
7	17
13	18
19	19

*RZ Aurigæ

d	h
July 25	19
31	20
Aug. 6	21
12	22
18	22
24	23
31	0

51.1908 Gemin.

d	h
July 1	10
5	11
9	11
13	11
17	11
21	11
25	11
29	12
Aug. 2	12
6	12
10	12
14	12
18	12
22	13
26	13
30	13

*RW Gemin.

d	h
July 4	12
10	5
15	23
21	16
27	10
Aug. 2	4
7	21
13	15
19	8
25	2
30	19

*U Columbæ

d	h
July 5	19
11	10
17	0
22	15
28	5
Aug. 2	19
8	10
14	0
19	15

Minima of Variable Stars of the Algol Type.—Continued.

*U Columbæ

d	h
Aug. 25	5
30	19

*RW Monoc.

d	h
July 4	16
8	11
12	7
16	2
19	22
23	17
27	13
31	8
Aug. 4	4
7	23
11	19
15	14
19	10
23	5
27	1
30	20

RX Gemin.

d	h
July 9	14
21	19
Aug. 3	0
15	6
27	11

**RU Monoc.

d	h
July 3	8
6	1
8	17
11	10
14	2
16	19
19	11
22	4
24	20
27	13
30	5
Aug. 1	22
4	14
7	7
10	0
12	16
15	9
18	1
20	18
23	10
26	3
28	19
31	12

**R Canis Maj.

d	h
July 1	4
4	14
8	0
11	9
14	19
18	5
21	15
25	1
28	10
31	20

**R Canis Maj.

d	h
Aug. 4	6
7	16
11	2
14	11
17	21
21	7
24	17
28	2
31	12

RY Gemin.

d	h
July 6	9
15	17
25	0
Aug. 3	7
12	14
21	21
31	5

*Y Camelop.

d	h
July 7	4
13	19
20	10
27	0
Aug. 2	15
9	6
15	20
22	11
29	2

RR Puppis

d	h
July 2	18
9	4
15	14
22	1
28	11
Aug. 3	21
10	8
16	18
23	4
29	15

**V Puppis

d	h
July 3	18
8	2
12	11
16	20
21	5
25	13
29	22
Aug. 3	7
7	15
12	0
16	9
20	18
25	2
29	11

†X Carinæ

d	h
July 4	20
10	6
15	16
21	2
26	11
31	21

†X Carinæ

d	h
Aug. 6	7
11	17
17	3
22	13
27	23

S Cancri

d	h
July 2	12
12	0
21	11
30	23
Aug. 9	11
18	22
28	10

S Velorum

d	h
July 4	3
10	2
16	0
21	22
27	21
Aug. 2	19
8	18
14	16
20	14
26	13

**Y Leonis

d	h
July 2	23
8	0
13	2
18	3
23	4
28	6
Aug. 2	16
7	17
12	19
17	20
22	21
27	23

**RR Velorum

d	h
July 3	15
9	5
14	18
20	8
25	21
31	11
Aug. 6	0
11	14
17	3
22	17
28	6

*SS Carinæ

d	h
July 5	16
12	7
18	21
25	12
Aug. 1	2
7	17
14	7
20	22
27	12

RW Urs. Maj.

d	h
July 4	0
11	9
18	17
26	0
Aug. 2	8
9	16
17	0
24	7
31	15

**Z Draconis

d	h
July 4	2
8	4
12	5
16	7
20	9
24	11
28	12
Aug. 1	14
5	16
9	18
13	19
17	21
21	23
26	0
30	2

*SS Centauri

d	h
July 5	15
10	14
15	13
20	12
25	11
30	10
Aug. 4	9
9	8
14	7
19	6
24	5
29	4

*δ Libræ

d	h
July 3	16
8	8
13	0
17	15
22	7
26	23
31	15
Aug. 5	6
9	22
14	14
19	5
23	21
28	13

*U Coronæ

d	h
July 1	19
8	16
15	14
22	12
29	10

*U Coronæ

d	h
Aug. 5	7
12	5
19	3
26	0

*SW Ophiuchi

d	h
July 2	11
7	9
12	6
17	3
22	1
26	22
31	20
Aug. 5	17
10	14
15	12
20	9
25	7
30	4

*SX Ophiuchi

d	h
July 2	13
6	16
10	19
14	22
19	1
23	4
27	7
31	10
Aug. 4	13
8	16
12	19
16	22
21	1
25	4
29	7

R Aræ

d	h
July 2	7
6	17
11	4
15	14
20	0
24	10
28	20
Aug. 2	7
6	17
11	3
15	13
19	23
24	10
28	20

**U Ophiuchi

d	h
July 1	7
3	20
6	8
8	21
11	9
13	21
16	10
18	22
21	10
23	23

Minima of Variable Stars of the Algol Type.—Continued.

**U Ophiuchi

d	h
July 26	11
29	0
31	12
Aug. 3	0
5	13
8	1
10	13
13	2
15	14
18	3
20	15
23	3
25	16
28	4
30	17

**SZ Herculis

d	h
July 2	1
4	12
6	23
9	10
11	21
14	8
16	19
19	6
21	16
24	3
26	14
29	1
31	12
Aug. 2	23
5	10
7	21
10	8
12	19
15	5
17	16
20	3
22	14
25	1
27	12
29	23

Z Herculis

d	h
July 1	5
5	5
9	5
13	5
17	5
21	5
25	4
29	4
Aug. 2	4
6	4
10	4
14	3
18	3
22	3
26	3
30	3

SX Draconis

d	h
July 4	0
9	4
14	8
19	12
24	17
29	21
Aug. 4	1
9	6
14	10
19	14
24	18
29	23

*RS Sagittarii

d	h
July 1	4
5	23
10	19
15	15
20	11
25	7
30	3
Aug. 3	23
8	19
13	15
18	11
23	7
28	3

*V Serpentis

d	h
July 2	0
8	22
15	20
22	18
29	15
Aug. 5	13
12	11
19	9
26	6

†RZ Draconis

d	h
July 2	3
7	15
13	3
18	15
24	4
29	16
Aug. 4	4
9	16
15	5
20	17
26	5
31	17

** RX Herculis

d	h
July 2	4
4	20
7	12
10	4
12	20
15	12
18	4
20	20
23	12
26	4

** RX Herculis

d	h
July 28	21
31	13
Aug. 3	5
5	21
8	13
11	5
13	21
16	13
19	5
21	21
24	13
27	5
29	21

*SX Sagittarii

d	h
July 3	12
7	16
11	20
16	0
20	3
24	7
28	11
Aug. 1	14
5	18
9	22
14	1
18	5
22	9
26	12
30	16

*RR Draconis

d	h
July 2	18
8	10
14	2
19	18
25	10
31	2
Aug. 5	18
11	10
17	2
22	17
28	9

**U Scuti

d	h
July 1	10
4	7
7	3
10	0
12	21
15	18
18	14
21	12
24	8
27	5
30	2
Aug. 1	22
4	19
7	16
10	13
13	9
16	6
19	3

**U Scuti

d	h
Aug. 22	0
24	20
27	17
30	14

*RX Draconis

d	h
July 2	6
6	1
9	20
13	15
17	10
21	5
25	0
28	19
Aug. 1	14
5	8
9	3
12	22
16	17
20	12
24	7
28	2
31	21

*RV Lyræ

d	h
July 3	5
10	10
17	15
24	19
Aug. 1	0
8	5
15	10
22	14
29	19

16 1908 Vulpec.

d	h
July 4	22
9	10
13	21
18	9
22	20
27	7
31	19
Aug. 5	6
9	18
14	5
18	17
23	4
27	16

*U Sagittae

d	h
July 5	0
11	18
18	13
25	7
Aug. 1	1
7	19
14	14
21	8
28	2

*Z Vulpec.

d	h
July 2	15
7	12
12	10
17	8
22	6
27	4
Aug 1	2
5	23
10	21
15	19
20	17
25	15
30	13

SY Cygni

d	h
June 3	13
9	13
15	14
21	14
27	14
Aug. 2	14
8	14
14	14
20	15
26	15

*WW Cygni

d	h
July 6	2
12	17
19	8
26	0
Aug. 1	15
8	6
14	21
21	13
28	4

SW Cygni

d	h
July 4	19
9	8
13	22
18	12
23	2
27	15
Aug. 1	5
5	19
10	9
14	23
19	12
24	2
28	16

VW Cygni

d	h
July 5	10
12	21
22	7
30	17
Aug. 8	4
16	14
25	0

Minima of Variable Stars of the Algol Type.—Continued.

*UW Cygni

	d	h
July	2	20
	9	17
	16	15
	23	13
	30	10
Aug.	6	8
	13	5
	20	3
	27	1

W Delphini

	d	h
July	3	17
	8	12
	13	7
	18	3
	22	22
	27	17
Aug.	1	13
	6	8
	11	3
	15	23
	20	18
	25	13
	30	9

RR Delphini

	d	h
July	4	20
	9	11
	14	1
	18	15
	23	6
	27	20
Aug.	1	10
	6	1
	10	15
	15	6
	19	20
	24	10
	29	1

RR Vulpec.

	d	h
July	3	15
	8	16
	13	18
	18	19
	23	20
	28	21
Aug.	2	22
	8	0
	13	1
	18	2
	23	3
	28	5

**VV Cygni

	d	h
July	2	7
	6	17
	11	3
	15	14
	20	0
	24	11
	28	21
Aug.	2	7
	6	18
	11	4
	15	14
	20	1
	24	11
	28	21

**28.1910 Cygni

	d	h
July	2	16
	5	14
	8	11
	11	9
	14	7
	17	5
	20	3
	23	0
	25	22
	28	20
	31	18

**28.1910 Cygni

	d	h
Aug.	3	15
	6	13
	9	11
	12	9
	15	7
	18	4
	21	2
	24	0
	26	22
	29	19

WZ Cygni

	d	h
July	31	18

*RT Lacertae

	d	h
July	3	15
	8	17
	13	19
	18	20
	23	22
	29	0
Aug.	3	2
	8	3
	13	5
	18	7
	23	9
	28	10

*TT Androm.

	d	h
July	4	14
	10	2
	15	15
	21	4
	26	16
Aug.	1	5
	6	18
	12	6
	17	19
	23	8
	28	20

21.1909 Andr.

	d	h
July	3	18
	7	21
	11	23
	16	2
	20	5
	24	8
	28	10
Aug.	1	13
	5	16
	9	19
	13	21
	18	0
	22	3
	26	6
	30	8

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

SX Cassiop

	d	h
July	10	6
Aug.	15	19

SY Cassiop.

	d	h
July	4	9
	8	11
	12	12
	16	14
	20	16
	24	18
	28	19
Aug.	1	21
	5	23
	10	0
	14	2
	18	4
	22	5
	26	7
	30	9

RW Cassiop.

	d	h
	(−5	19)
July	5	7
	20	2
Aug.	3	22

SU Cassiop.

	d	h
	(−0	22)
July	2	17
	4	16
	6	15
	8	13
	10	12
	12	11
	14	10
	16	8
	18	7
	20	6
	22	5
	24	4
	26	2
	28	1

SU Cassiop

	d	h
July	30	0
	31	23
Aug	2	21
	4	20
	6	19
	8	18
	10	17
	12	15
	14	14
	16	13
	18	12
	20	10
	22	9
	24	8
	26	7
	28	6
	30	4

RX Aurigæ

	(−4	0)
July	4	9

RX Aurigæ

	d	h
July	16	0
	27	16
Aug.	8	4
	19	22
	31	13

SX Aurigae

	d	h
July	1	14
	3	2
	4	15
	6	4
	7	17
	9	6
	10	18
	12	7
	13	20
	15	9
	16	21
	18	10
	19	23
	21	12

SX Aurigæ

	d	h
July	23	0
	24	13
	26	2
	27	15
	29	3
	30	16
Aug	1	5
	2	18
	4	6
	5	19
	7	8
	8	21
	10	9
	11	22
	13	11
	15	0
	16	13
	18	1
	19	14
	21	3

Maxima of Variable Stars of Short Period not of the Algol Type.

Continued.

SX Aurigæ		W Gemin.		W Carinæ		RZ Centauri		RZ Centauri	
d	h	d	h	d	h	d	h	d	h
Aug. 22	16	(−2	2)	Aug. 3	16	July 1	9	Aug. 26	14
24	4	July 1	4	8	1	2	7	27	13
25	17	9	2	12	10	3	6	28	11
27	6	17	0	16	19	4	4	29	10
28	19	24	22	21	4	5	3	30	8
30	7	Aug. 1	20	25	13	6	1	W Virginis	
31	20	9	18	29	22	7	0	(−8	5)
SY Aurigae		17	16			7	22	July 14	4
July 4	4	25	14	S Muscæ		8	21	Aug. 1	11
14	7			(−3	11)	9	19	18	17
24	11	ζ Gemin.		July 2	8	10	18	V Centauri	
Aug. 3	14	(−5	0)	12	0	11	16	(−1	11)
13	17	July 2	14	21	15	12	15	July 4	21
23	21	12	18	31	7	13	13	10	9
Y Aurigae		22	21	Aug. 9	23	14	12	15	21
(−0	18)	Aug. 2	1	19	14	15	10	21	9
July 3	18	12	5	29	6	16	9	26	21
7	15	22	8			17	7	Aug. 1	9
11	11			T Crucis		18	6	6	21
15	8	RU Camelop.		(−2	2)	19	4	12	8
17	5	(−9	12)	July 4	12	20	3	17	20
23	1	July 5	11	11	5	21	1	23	8
26	22	27	17	17	23	22	0	28	20
30	18	Aug. 19	10	24	16	22	22	R Triang Austr.	
Aug. 3	15			31	10	23	21	(−1	0)
7	12	V Carinæ		Aug. 7	3	July 3	2	July 3	2
11	8	(−2	4)	13	21	6	11	6	11
15	5	July 6	15	20	15	9	21	9	21
19	2	13	7	27	8	13	6	13	6
22	22	20	0			16	15	16	15
26	19	26	17	R Crucis		20	1	20	1
30	15	Aug. 3	9	(−1	10)	23	10	23	10
RZ Gemin.		10	2	July 3	7	26	19	26	19
(−1	7)	16	19	9	3	30	5	30	5
July 4	22	23	11	14	22	Aug. 1	8	Aug. 2	14
10	11	30	4	20	18	2	6	5	23
15	23			26	14	3	5	9	9
21	11	T Velorum		Aug. 1	10	4	3	12	18
27	0	(−1	10)	7	6	5	2	16	3
Aug. 1	12	July 3	6	13	1	6	0	19	13
7	0	7	21	18	21	6	23	22	22
12	13	12	13	24	17	7	21	26	7
18	1	17	4	30	13	8	20	29	17
23	14	21	20			9	18	S Triang. Austr.	
29	2	26	11	S Crucis		10	17	July 3	23
RS Orionis		31	2	(−1	12)	11	15	10	7
(−2	0)	Aug. 4	18	July 1	16	12	14	16	14
July 7	21	19	9	6	9	13	12	22	22
15	11	14	0	11	1	14	11	29	6
23	0	18	16	15	18	15	9	Aug. 4	14
30	13	23	7	20	11	16	8	10	21
Aug. 7	3	27	22	25	3	17	6	17	5
14	16	W Carinæ		29	20	18	5	23	13
22	6	(−1	0)	Aug. 3	12	19	3	29	21
29	19	July 4	2	8	5	20	1	S Normæ	
T Monoc.		8	11	12	21	20	23	(−4	10)
(−9	23)	12	20	17	14	21	22	July 5	1
July 4	23	17	5	22	6	22	20	14	19
31	23	21	13	26	23	23	19	24	13
Aug. 28	0	25	22	31	16	24	17	Aug. 3	7
		30	7			25	16	13	1
								22	19

Maxima of Variable Stars of Short Period not of the Algol Type.

Continued.

RV Scorpii

	d	h
	(−1	10)
July	3	2
	9	3
	15	5
	21	6
	27	8
Aug.	2	9
	8	11
	14	12
	20	14
	26	15

RV Ophiuchi Minimum

July	4	16
	8	8
	12	1
	15	17
	19	10
	23	2
	26	19
	30	11
Aug.	3	4
	6	20
	10	13
	14	5
	17	22
	21	14
	25	7
	28	23

X Sagittarii

	(−2	22)
July	2	0
	9	1
	16	1
	23	1
	30	1
Aug.	6	2
	13	2
	20	2
	27	2

Y Ophiuchi

	(−6	5)
July	5	12
	22	14
Aug.	8	17
	25	20

W Sagittarii

	(−3	0)
July	5	10
	13	9
	20	14
	28	5
Aug.	4	19
	12	9
	19	23
	27	14

Y Sagittarii

	d	h
	(−2	2)
July	4	0
	9	19
	15	14
	21	8
	27	3
Aug.	1	21
	7	16
	13	10
	19	5
	25	0
	30	18

U Sagittarii

	(−2	23)
July	6	18
	13	14
	20	7
	27	1
Aug.	2	19
	9	14
	16	4
	22	21
	29	16

β Lyræ

	(−3	7)
	(−3	2)
July	5	26
	12	7
	18	23
	25	6
	31	22
Aug.	7	4
	13	20
	19	2
	26	18

κ Pavonis

	(−4	7)
July	2	15
	11	17
	20	19
	29	22
Aug.	8	0
	17	2
	26	4

U Aquilæ

	(−2	4)
July	6	2
	13	3
	20	3
	27	4
Aug.	3	4
	10	5
	17	6
	24	6
	31	7

U Vulpec.

	d	h
	(−2	3)
July	1	17
	9	17
	17	16
	25	16
Aug.	2	15
	10	15
	18	14
	26	14

SU Cygni

	(−1	7)
July	3	8
	7	5
	11	1
	14	21
	18	18
	22	14
	26	10
	30	6
Aug.	3	3
	6	23
	10	19
	14	16
	18	12
	22	8
	26	5
	30	1

η Aquilae

	(−2	6)
July	1	4
	8	8
	15	12
	22	17
	29	21
Aug.	6	1
	13	5
	20	9
	27	14

S Sagittae

	(−3	10)
July	1	8
	9	17
	18	2
	26	11
Aug.	3	20
	12	6
	20	15
	29	0

X Vulpec.

	(−2	1)
July	2	19
	9	2
	15	10
	21	18
	28	1

X Vulpec.

	d	h
Aug.	3	9
	9	16
	16	0
	22	8
	28	15

V Vulpec. Minimum

Aug.	27	16

X Cygni

	(−6	19)
July	1	7
	17	17
Aug.	3	2
	19	11

T Vulpec.

	(−1	10)
July	3	21
	8	6
	12	16
	17	3
	21	14
	26	0
	30	10
Aug.	3	21
	8	7
	12	20
	17	4
	21	16
	26	1
	30	12

TX Cygni

July	4	9
	19	2
Aug.	2	20
	17	13

VY Cygni

	(−2	14)
July	5	21
	13	17
	21	14
	29	10
Aug.	6	7
	14	4
	22	0
	29	21

VZ Cygni

	(−1	1)
July	3	8
	8	5
	13	1
	17	22
	27	16

VZ Cygni

	d	h
Aug.	1	12
	6	9
	11	6
	16	3
	20	23
	25	20
	30	17

Y Lacertae

	(−1	10)
July	2	12
	6	19
	11	3
	15	11
	19	19
	24	3
	28	10
Aug.	1	18
	6	2
	10	10
	14	18
	19	2
	23	9
	27	17

δ Cephei

July	2	4
	7	13
	12	22
	18	6
	23	15
	29	0
Aug.	3	9
	8	17
	14	2
	19	11
	24	20
	30	5

Z Lacertae

July	8	4
	19	1
	29	22
Aug.	9	19
	20	16
	31	13

RR Lacertae

July	5	3
	11	13
	17	23
	24	9
	30	19
Aug.	6	5
	12	15
	17	1
	25	12
	31	22

Maxima of Variable Stars of Short Period not of the Algol Type.

Continued.

V Lacertae		X Lacertae		SW Cassiop.		RS Cassiop.		RY Cassiop.	
d	h	d	h	d	h	d	h	d	h
(−1	10)	July 1	15	July 3	20	(−1	19)		
July 4	21	7	0	9	6	July 3	14	(−7	10)
9	21	12	12	14	17	9	21	July 6	12
14	20	17	23	20	3	16	4	18	15
19	20	23	10	25	13	22	11	30	19
24	19	28	20	31	0	28	18	Aug. 11	22
29	19	Aug. 3	7	Aug. 5	10	Aug. 4	1	24	2
Aug. 3	19	8	17	10	21	10	8		
8	18	14	4	16	7	16	16		
13	18	19	15	21	17	22	23		
18	17	25	1	27	4	29	6		
23	17	30	12						
28	17								

COMMUNICATIONS QUESTIONS AND ANSWERS.

[This department is designed especially for the use of amateurs. Beginners are invited to send in their puzzling questions. The editors will try to see that answers are given to reasonable questions but will not hold themselves responsible for the correctness of the views expressed in the communications which may find place here. All communications should be brief.]

The Variation in the Rotation Period of Jupiter and Saturn:— According to the most reliable observations the rotation of Jupiter and Saturn fluctuates in such a way, that the rotation period becomes shortest when the planets are at or near perihelion, and longest when the planets are at or near aphelion, but that the difference in this respect is many times greater in the case of Saturn than in the case of Jupiter.

As to the variation of the rotation period of Jupiter, the following observations show the variation in question conclusively:

Observers	Time of Rotation h	m	s	Years		
Cassini	9	56	0	in 1665	Jupiter's aphelion	1662
"	9	55	51	" 1672	" "	Dec. 1673
"	9	51	0	" 1690		
"	9	51	0	" 1691	Jupiter's perihelion	1691
"	9	50	0	" 1692		
William Herschel	9	54	53	" 1788	" "	1786
Lord Rosse	9	54	55	" 1873		
Flammarion	9	55	45	" 1874	Jupiter's aphelion	1875
Denning	9	50	5	" 1881	Jupiter's perihelion	1881

According to these observations the difference in the rotation period is five or six minutes. It may be that the difference is less, yet the fact remains that there is some difference and that the planet rotates swifter while at perihelion than when it is at aphelion. There are many other observations of the rotation of Jupiter, but in order to be brief I have omitted them here; yet it may be stated that they all show the same effect.

In 1793 and the early part of 1794 Sir William Herschel found from 154 rotations of Saturn a rotation period of ten hours and sixteen minutes. As the planet was at perihelion in 1796, Herschel found the rotation period at a time when the planet was near perihelion. Observations of Saturn's rotation

while near aphelion were made in 1903 by some of the ablest astronomers of the world, and a rotation period of ten hours and thirty-eight minutes was found. Discussing this subject Mr. Denning writes in *Knowledge* for December 1903: "There have been several spots visible, both light and dark, and the chief one, first seen in June 1903, has been watched at Bristol during the past five months, and its main rotation period has been, as near as possible, ten hours thirty-eight minutes." Mr. Graff of Hamburg found however, the rotation period from the same spot to be ten hours thirty-nine minutes. It may be remarked that the spot from which Herschel determined the rotation period was situated in the south temperate zone, and that the spot upon which the latter observation was made was in the north temperate zone.

We observe, then, that the rotation period of Saturn in 1903 when the planet was near aphelion was twenty-two minutes longer than in 1793-94 when the planet was near perihelion. Beside the above there are also other valuable observations of spots on Saturn, but which, however, lead to no different result than the above. In the summer of 1877 Professor Asaph Hall observed from a bright equatorial spot of Saturn a rotation period of ten hours fourteen minutes and twenty-three seconds. As the planet was at perihelion in 1885 it follows that this observation gives the rotation period for the equatorial region when the planet is midways between aphelion and perihelion.

Allowance must here be made for the fact that the rotation period of Saturn is always shorter in the equatorial regions than in higher latitudes. In 1891, when the planet was two years journey nearer perihelion than in 1877, Mr. A. S. Williams of Brighton found a rotation period of ten hours thirteen minutes. Again in 1858 Dawes observed a spot on the south hemisphere of Saturn somewhere about lat. 50°. This was two or three years after perihelion. Consequently the rotation should at this time be of about the same value as in 1793-94 as observed by Herschel, with the exception of the difference which would prove to be due to the difference in latitudes. This seems to be well established by Dawes' observation. His spot appears to be about 20° farther from the equator than the one observed by Herschel and, as matter of course, its rotation period had to be longer than the rotation period of Herschel's spot, namely ten hours, twenty-five minutes. This observation brings out the same fact as the one arrived at above. Notwithstanding spots in high latitudes move much more slowly than near the equator it shows that the rotation period even at about lat. 50° while the planet is near perihelion, is thirteen minutes shorter than the rotation period at about lat. 30°, while the planet is near aphelion.

There may be other observations at different times, which furnish somewhat different results; but none of them, as astronomers well know, has any great weight in comparison with those which are here given; and we may, therefore, accept the variation of Saturn's rotation as a scientifically established fact. It may be left undetermined at present how large this variation is, yet this much seems certain, it is about twenty-five minutes.

N. MISTOCHLES.

Notes on Centaurus and Crux.—Among the constellations visible in the southern hemisphere the Southern Cross and the Centaur are two of the most noteworthy, the former from the closeness and beautiful arrangement of its bright stars and the latter from its great extent and numerous bright components. To the astronomer both these constellations are of great interest from the objects which they contain.

The Milky Way in this region is noteworthy. Passing from Argus through Crux and Musca, through α and β Centauri, enveloping Circinus, skirting the southern triangle, it goes on into Lupus, Norma and Ara. It is very bright in this region but not uniformly. Near the variable η Argus it is brightened by the nebula. Beyond this there is a bright spot due to a large star cluster which gives a tailed appearance to a fifth magnitude star* in Argus. Close to λ Centauri, a bright star of magnitude 3.3, are two large clusters just visible to the naked eye on a favorable night. The region in Crux owes its brightness to a luminous area composed of comparatively bright stars which is immediately succeeded by the coal sack whose inky blackness is only relieved by one faint sixth magnitude star. The bright stars β and α Centauri come next after a short interval, while α Centauri is followed by a large dark rift, not however of such intense darkness as the coal sack. Following this star there is a group of fifth magnitude stars including β and γ Circini which will well repay study with a low power.

Crux Australis. The four brightest stars in this constellation are α (mag. 1.0) β (mag. 1.5) γ (mag. 1.6) and δ (mag. 3.1). Between α and δ is a fourth magnitude star ϵ of a red color.

α *Crucis* is a double star, magnitudes 1 and 1¾, separation about 5″. No parallax has, I believe, been found for this star so its distance must be very great in spite of its brilliancy; neither has any orbit been found for the system although the proper motion of both is the same, they are surrounded by a ring of stars in which the two lie stationary. When α Crucis is looked at with a low power a fifth magnitude star can be seen 90″ to the south, so in one sense this is a triple star.

β *Crucis* is a very white star. There is a sixth magnitude star about 2′ to the north. No parallax has been found for β Crucis. It might be noted that the proper motions of α and β Crucis, although very slow, are almost identical.

Proper motion	α Crucis in R. A. $-.^s0064$ —	in D. $-.''039$
	β Crucis " " $-.^s0064$	" " $-.\ 033$

The angular distance of these two stars is about 3° or 4° and we might hazard the opinion that although widely separated they are at about the same distance from us.

North of the cross is the little constellation Musca. α and β Muscae are a little over a degree apart and like α and β Crucis there is about half a magnitude of brightness between them; they also are moving in the same general direction as the last two and their proper motions are singularly alike.

α Muscae (mag. 2.9) in R. A. $-^s.0088$ in D $-''.029$
β Muscae (mag. 3.3) " " $-.0085$ " " $-\ .027$

I do not know whether or not any parallax has been found for these two stars. If so it would be of interest to know the actual distance between them.

Just a little south and following β Crucis on the northern edge of the coal sack is a very beautiful cluster surrounding the reddish star κ (mag. 7). The brighter stars of this cluster can be seen with a low power as a little compressed triangle of stars.

All this region immediately surrounding and including the Cross is very rich in naked eye stars. Next to the Pleiades it is reckoned the most densely crowded region of the heavens in spite of the barren coal sack.

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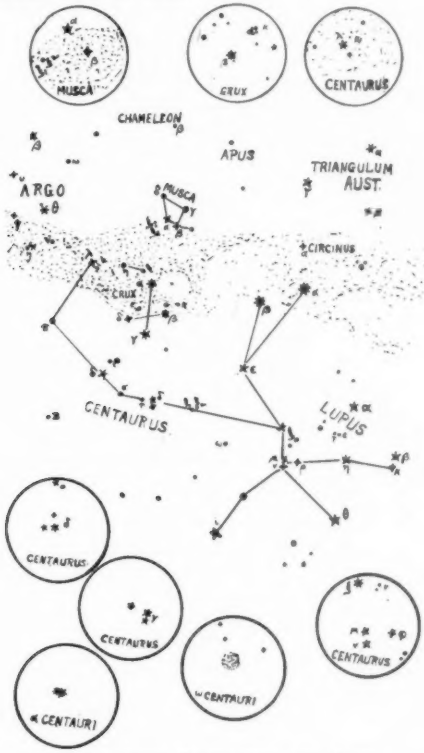
* This star is about one-third of the way between θ Argus and π Centauri.

CENTAURUS. The two stars known as the pointers, α and β Centauri, because they indicate the position of the Cross, are brilliant first magnitude stars. α is the third brightest star in the heavens (mag. 0.1), while β is rated at mag. 0.8. Here we have three first magnitude stars close together. Indeed there is no other instance of which I am aware, where a few degrees separates such brilliant orbs.



REGION AROUND CENTAURUS AND CRUX.

α and β Centauri are very dissimilar stars and it is only our point of view that makes the angular distance that separates them so small.

α Centauri is the nearest known fixed star. It is of the solar type and has the large proper motion of 3."67 per annum. It is a double star, a true binary, with a companion somewhat brighter than the second magnitude. A revolution is completed in 81 years and the mass of either component is about the same as the Sun, the brighter a little greater, the fainter a little less. The pair can easily be seen in a small telescope with a power of about 30 or less, the distance separating them being about 17." α Centauri has a parallax of 0."76 and is between four and four and a half light years off. The distance between the components is about twenty-three times the Sun's distance from us or somewhat greater than that of Uranus from the Sun.

β *Centauri* is very much farther away from us. It belongs to the Sirian class of suns and has a proper motion of only three or four seconds in a hundred years. Its parallax is, I believe, 0.05, so that its light would take about 65 years to reach us.

Among the other matters of interest in this constellation are as follows: Two stars, μ and ν, of very similar brightness (3.3 and 3.5), are about $\frac{3}{4}°$ apart while ϕ, only a little less bright, is about $1\frac{1}{2}°$ away. This pair is repeated in κ Centauri (mag. 3.3) and β Lupi (mag. 2.8) which, however, are somewhat wider apart.

It is interesting to note that the region surrounding α Lupi is very rich in naked eye stars. γ Centauri is a binary system composed of two stars of nearly equal magnitude separated by a little over 1″ and having a period of 86 years. It is a star of the Sirian type and is a naked eye double. A star of the fifth magnitude lies closely north of it while the fourth magnitude star, τ, is about half a degree preceding. δ Centauri (mag. 2.8) is another naked eye double, a very small star just preceding it by a few minutes of arc. Slight magnification shows a sixth magnitude star to the south, forming a very pretty triple. ρ Centauri is about $1\frac{1}{2}°$ south. ϵ, ζ and η Centauri are bright third magnitude stars. θ is a little less than the second magnitude and of an orange color.

One of the most interesting objects in the constellation is the globular cluster, ω Centauri, nearly midway between ζ and γ and a little to the north. A somewhat hazy fourth magnitude star, or what looks like a star, can be seen in it. With a low power it has a comet-like appearance, a round hazy patch of about 40′ diameter. Greater power resolves it into a wonderful cluster of stars of the 13th and 15th magnitude but I think a description and discussion of this unique object might be left to larger works. Suffice it to say that the number of stars has been estimated at from 6,000 to 10,000. Over a hundred variables have been found in this cluster.

BERNARD THOMAS, M. B. Ch.

Glenorely, Tasmania.

Observations of Mercury:—On April 6, between 7:00 and 7:20 P M., Mercury was observed, this being the first observation of the planet made by me at this elongation. The body was very low in the west, and rather to the north, roughly 5°, from Saturn. Mercury was extremely difficult to observe on this date, being so near the smoky horizon. Powers 56 and 84 diameters showed a small disc, approximately 50% illumined. The next observation of the planet was made on the ninth, at about $6^h\ 45^m$, sidereal time, in broad day light, it being found by aid of the circles on the equatorial of my 3″ refractor. Mercury resembled a little Moon on this date, silver-white in appearance with obviously a disc of from 40 to 50% illuminated. The "horns" were very marked, and stood out plainly against the sky, though the Sun was very high. The planet closely resembled Venus in similar phase, only, of course, being much smaller. It was found to be white or yellow, after the Sun had set, and to the naked eye, yellowish or even slightly pinkish. Mercury had moved considerably since the sixth and was probably brighter than Saturn under similar conditions. On the evening of the fourteenth, Mercury was again observed, but little could be noted, as it was very low, observing thus

being rendered almost impossible. I have found day observations of both Mercury and Venus far superior in nearly all circumstances to nocturnal ones.

This has been an extremely favorable elongation for observers without equatorials to catch this shy little body, as observed from Chicago.

FREDERICK C. LEONARD

Leonard Obs'y., Madison Pk.
Chicago, Ill.

New Double Stars.—The following four new double stars have been found with the 6½-inch Clark refractor and have been measured with considerable difficulty.

ρ 71 B.D. + 0° 2085

$7^h\ 42^m\ 49^s$, $-0°\ 2'$, ($9^m.6$, $10^m.5$) 13 March, 1911.

1911.200	120°.2	6″.04
.211	120 .4	6 .19
.227	121 .9	5 .80
.230	120 .1	5 .86
1911.217	120 .6	5 .97

ρ 72 B.D. + 31° 1891

$8^h\ 45^m\ 33^s$, 30° 58′, ($9^m.7$, $10^m.2$) 6 March 1911.

1911.180	189°.3	5″.06
.187	189 .2	5 .71
.193	188 .7	5 .41
1911.187	189 .1	5 .39

ρ 73 $11^h\ 35^m.5$, $-5°\ 40'$ (rough place)

AB ($9^m.8$, $10^m.5$) 18 April, 1911.

	1911.312	361°.5	3″.30
	.315	360 .0	3 .55
	.340	359 .1	3 .28
	1911.322	360 .2	3 .37
AC,C(10^m)	1911.312	55.6	86.62
AB,D(12^m)	1911.312	100.	120. (estimate)

Confirmed the duplicity of AB May 5 with the university 8-inch Clark refractor. This pair is about 20′ north and about 10 min. preceding B.G.C. 5807 Σ 3072. The exact position and better measures will be given later.

ρ 74 $14^h\ 11^m\ 30^s$, 23° 21′

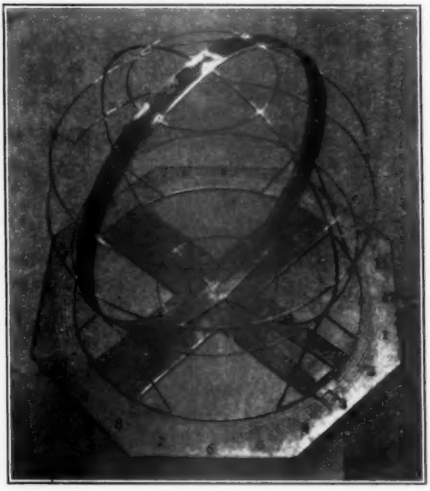
50^s 3 following and 6′.4 north of B.D. 23° 2668 ($9^m.5$, $9^m.8$) 7 April, 1911.

1911.266	284°.7	7″.52
.274	284 .6	7 .11
.346	284 .2	6 .79
1911.295	284 .5	7 .14

Syracuse, N. Y. E. D. ROE, JR.

A New Sun-Dial.—The improved Sun-Dial and "Locometer" which I have lately invented and applied for a patent on the same, is the result of my study of popular astronomy for the last two or three years. I am lead to believe it will be of interest to your many amateur readers and am therefore sending this to you in order that you may give a description of the device in your next issue, if you are of the opinion it will interest your reader.

By it one is able to get the clock time, the Sun time, the latitude and the longitude of the place of observation to within one-half minute of time. It is constructed of sheet copper and copper wires. The dial-plate is 24 inches in diameter. The time scale, which is a part of the dial plate is divided into five minute spaces, with appropriate markings for the hours, halves and quarter hours. All the part above this dial-plate is constructed rigidly and rotates at the center of said dial plate. The part above the circular plate lying on the dial plate is constructed as a skeleton globe with the equator, tropics of Cancer and Capricorn and the polar circles parallel to the dial plate and one meridian



THE LOCOMETER.

of longitude and what I call a "circular frame" crossing said circles at right angles. There is a small perforation in the circular frame at the point where it is crossed by the equatorial line, which admits a ray of sunlight which when centered on the center line of said circular frame, inside and opposite to the point of entrance, which is done by rotating by hand all that part of the machine above the dial-plate, will bring the time pointers to the correct time on the dial-plate, the machine having been properly placed and adjusted as hereinafter explained. To be used as a local sun-dial, the machine should be placed upon a firm base so that a line drawn through the hour points at the numerals six on the dial shall be in a true north and south line, and a line drawn through the hour lines at the numerals twelve

shall be a true east and west line, and the base level, and the dial plate tipped to the co-latitude of the place, the face of the dial being to the north when used north of the equator.

When used as a Locometer the base must be adjusted to a perfect level, the dial plate hinged to the base so the dial may be tilted from an horizontal to a vertical position so that when at a vertical position the dial-plate will be in a vertical plane due east and west. The circular frame, heretofore mentioned, is scaled on the inside opposite to the perforation into degrees and fractions of degrees to the extent of forty-seven degrees in each direction from the equatorial line. To adjust the machine in an unknown locality the ray of sun light entering the perforation must be centered on the central line of said scale and on the point in said scale for the Sun's declination on the day of observation. The degrees and fractions thereof will be double on the scale of that shown in the table of the Snn's declination because the scale is drawn from a radial point at the center of the circular frame and the radial point of the Sun's ray is in the periphery of the circuiar frame and opposite to the scale. Then the quadrant which shows at the right end of the base is securely clamped in the position it is placed by the tilting done to bring the ray o sun-light to the proper point in the declination scale. The quadrant is carried by the dial plate and is scaled to degrees and fractions of degrees from the zero point at the lower end to ninety degrees at its junction with the dial plate, so that an indicating line or point on the base which comes in line with the ninety on said scale when it is placed in a horizontal position, will always indicate the latitude of the place of observation when the Sun's declination has been determined as above described. The longitude is determined by having a watch carrying Greenwich time and converting the time shown on the dial into longitude, and conforming to Greenwich longitude. For example, if the dial show three o'clock P.M. and the watch with Greenwich time show nine hours, and twenty minutes P.M., I find that the Sun is on the 135 meridian west of Greenwich and that it is forty-five degrees west of the meridian of the place of observation. I therefore subtract the 45 from the 135 which gives 95 as the longitude of the place of observation. This is the only mathematical calculation required when observations are made by the Sun. For observations on stars I attach a small telescope and secure the same results with the same ease.

The model for which this photograph was taken was made by myself with the assistance of a tinner, a jeweler and a blacksmith, so it is not a perfect piece of mechanism, yet I am able to get the time from one hour after sunrise till within one hour of sunset, at any time when the Sun is shining to within one half minute of the correct standard and Sun time, and the same result from any known star or planet near the equator, visible to the naked eye. Corrections can be made daily for the time equation by a device that works in connection with the time pointers.

I have tried it out pretty thoroughly with this crude machine and am well satisfied that with a carefully constructed machine on the lines demonstrated by this, the time, latitude and longitude can be determined with great accuracy and with no other mathematical calculation than mentioned above.

Sac City, Iowa, CHAS. L. EARLY.

An Interesting Occultation.—Last evening as I turned my 6" telescope to observe the occultation of 57 B Leonis, I saw that here there would be no occultation of that star; but I noticed a star close to the Moon's edge which was bright enough to watch easily. For two or three minutes it seemed to slide along the limb of the Moon, and I thought that it might not touch. But suddenly it disappeared. For a moment, I turned from the eyepiece. On looking again, I was surprised to see the star. In about two seconds it flashed out of sight, remaining invisible about two seconds, then reappearing for ten or fifteen seconds. Within about two minutes, including its first disappearance, it was occulted five times. After the last time it was hidden for about a minute, when it made its final reappearance. Of course, the tops of mountains or crater-points caused these successive occultations. Between one reappearance and disappearance, I thought its light slightly diminished. But owing to its proximity to the N. point of the illuminated half of the Moon, and the light in the field of view being unequally distributed, no accurate estimate of its light could be made. Power used was 125. My telescope was made in 1870 by Alvan Clark and I am more and more appreciating what it means to possess and use an instrument from the hand of that famous constructor of objectives.

Henniker, N. H. TILTON C. H. BOUTON.

Cincinnati Astronomical Society.—The first annual meeting of the Society was held in the Christ Church Parish House, Friday evening May 12. At previous meetings the constitution and by-laws had been adopted, except deciding on the amount of the annual dues. After some discussion the dues were fixed at three dollars a year for active members and two dollars for associates. This will make it possible for a course of illustrated lectures to be given during the year by outside astronomers. The regular meetings are to be held on the second Friday of each month from October to May.

The event of the evening was the lecture by Professor Barnard of Yerkes Observatory on "Photographic Revelations in Astronomy." The audience was highly pleased with his fine slides and many also stayed to meet Dr. Barnard and see three stereoscopic views of Morehouse's Comet, which could not be projected in the lantern.

Sixty-five men and women have come in as Charter Members. The election of offices for the coming year resulted as follows: DeLisle Stewart, president; W. C. Cooder, vice-president; Robert H. Corey, secretary; A. D. Fisher, treasurer; A. D. Alcorn, P. B. Evens, J. B. Griese, A. P. Henkel, C. H. Norton, M. C Slutes, directors. President Taft was unanimously elected the first honorary member.

A course of ten illustrated astronomy lectures has been given on Friday evenings in January, February and March at the rooms of the Natural History Society by Dr. Stewart. Toward the close of these lectures a committee was nominated to plan for the organization of this Society.

On April 7, Professor G. W. Ritchey delivered his lecture on the new 60 inch Mt. Wilson reflector and its work, at the Cincinnati Womens Club.

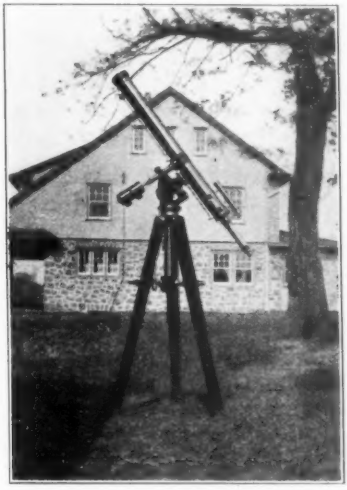
Many owners of small telescopes and opera glasses as well as readers of astronomy are pleased over the formation of a society for mutual study and encouragement. The name will remind many of the early Astronomical Society organized by O. M. Mitchel in 1842, which led to the purchase of the large telescope and erection of the Mt. Adams Observatory. That society went out of existence in 1872, when the support of the Old Observatory was

assumed by the city of Cincinnati. The present society is especially interested in the study of the newer lines of astronomical and astro-physical research: it plans to hold its meeting in various institutions and in different parts of the city.

Astronomers and astro-physicists whose plans for the next year might bring them near Cincinnati are asked to send dates and particulars regarding their lectures to the secretary.

Dayton Astronomical Society.—Dr. Barnard was in Dayton, O. May 10, to deliver his lecture before the Dayton Astronomical Society. It is expected that a museum of aviation as a memorial to the Wright brothers and a popular observatory are to be erected jointly by the Aero Club and the Astronomical Society at Dayton.

Description of an Amateur's Telescope, constructed partly by himself.—The objective of my four-inch refractor, the equatorial head, eyepieces and other parts, were furnished by the J. A. Brashear Company, my own work consisting of fitting the diaphragms, making finder brackets, declination axis counterbalances, tripod, etc.



The brass tube is reinforced at the center ring by a rather long inside ring of maple, fitting tightly. The diaphragms are made of built-up maple, two inches long, oiled and blackened, and fitting tightly. The wood used was old and thoroughly seasoned, and shows no tendency to warp or swell. The extra weight of the mounting requires an additional counterpoise, but as the whole is well balanced the performance, particularly when focussing, adjusting the helioscope, etc., is very steady.

I have never had any sympathy with the demand for light telescope construction, with unsteady stands, paper-thin tubes, axes of insufficient rigidity, and all the other devices calculated to make the image of an object dance about in the field of view. The desideratum is a quiet image (as far of course as atmospheric influences will permit) and modern mechanical possibilities certainly afford the means of making a telescope mounting so rigid as to make observation a pleasure and continuous work less difficult than it would otherwise be.

Reasoning along this line I made a tripod of solid mohogany with a heavy cast iron head neatly machined, to which is fitted a brass tube center post eighteen inches long. Steel bolts of one inch diameter pass through the legs and a cast iron ring surrounding the lower end of this center post, and are fastened to either side of the legs by large brass nuts. The mortise through which these bolts pass is so shaped as to allow a six-inch range of adjustment. Steel screws of the same diameter form the feet of the tripod, passing through bronze plates, thus affording a nice means of adjusting the spirit level in the equatorial head.

Of course, this construction is somewhat costly and is probably as heavy as anyone would care to handle in and out of the house. On the onher hand it requires only a few minutes to set up, and I feel certain of being rewarded for my trouble whenever the "seeing" is good.

Another thing that has impressed me after a careful reading of many books on the subject is that telescopes of apertures of the class to which mine belongs have not had their full powers developed. Few amateurs will take the time and do the work necessary to this end and consequently do not realize all that an object glass of moderate size is capable of. Knowing that a four-inch objective of the Brashear quality must have wonderful possibilities with careful, persistent effort on the observer's part, I determined that everything in my equipment should be high grade and I gradually purchased a series of eyepieces of the different constructions in order that I might have every advantage of light, field and power within the capacity of a four inch aperture, and the end has abundantly justified the means. I have frequently used 300 on Mars and Jupiter. On one occasion the definition of the latter was startlingly clear and cameo-like for a few minutes at a time. Mr. McDowell made me a 3-lens positive of 1¼ equivalent focus, with cross-wires, which gives a power of 48 and was just the right thing for Halley's comet; a lower power being insufficient and additional power spreading the light too much.

For a dew-cap I use black blotting paper, fitting neat and close over the objective cell and head ring, and as this is non-reflecting and absorbs moisture readily it has answered the purpose very well.

If anyone should find the foregoing sufficiently interesting to care for further details I should be very glad to respond.

May 2, 1911. H. B. RUMRILL.

The Planetary System. Its Kinship to the Solar Orb.—Not only are the planets the children of the Sun in the sense that they are under its control and are receiving from it the essentials of life, namely heat and light, but also because they are its very flesh and bone; that is, they have been ejected or exploded from the solar body.

A few principles of astronomical mechanics lead us to believe in this theory.

They are:

1. "Circular motion of all the planets perpendicular, or about, to the axis of the Sun."

2. "Circular motion of all the planets from west to east in the same direction as the rotary motion of the Sun."

3. "The elliptical form of that circular motion peculiar to all the planets."

4. The greater velocity of the planets nearest to the Sun and slower velocity of those farthest from that body, in their circular motion.

All the above characteristics pertaining to the movement of the eight planets would with minute exactness be duplicated, should the Sun presently give birth to a new world. This new world, should it come into being, naturally, the event would take place in some part of the equatorial zone of the Sun, in obedience to the ejecting power of its centrifugal motion.

The determining cause of that birth, we conjecture, would be a "contact," a contact of another body with the Sun; a mass of matter coming from the depths of space shooting toward the Sun; a body that would transcend, in its inconceivable velocity, the repelling laws of the solar radiation, refusing to diverge, to curve or to recede but violently striking straight and deep down into the solar orb. Then the generation and expansion of fluids or gases, resulting from the impact, would develop the terrifying energy which would expel with as much violence the disturbing substance.

The body, now ejected from the Sun would receive at once two impulses; one straight up, or zenithward, from the force of the explosion, the other eastward from the effect of the rotary motion of the Sun. However, the body, as it would emerge from the interior of the Sun to its surface, could not at the same time obey those two impulses but naturally would follow an oblique line between the two, that is, between the perpendicular and the eastward-horizontal line. If the force of the explosion was extremely violent; the oblique line would part but little from the vertical line, while a milder exertion of that force would cause the body to incline to a greater extent toward the east, in response to the rotary motion of the Sun. The greater the violence of the explosion, the quicker its fearful work, but proportionately, the shorter time to rotate would the Sun have during its occurrence; consequently to a lesser degree would the eastward motion be impressed on the body ejected.

In case an explosion from the Sun should be so violent as to be instantaneous that is as to allow no succession of time during its occurrence, then the eastward motion of the Sun would not be felt at all because the Sun would have no time to turn on its axis; the instantaneousness of the explosion would still the Sun, so to speak. The body thus darted into space would receive no eastward impression but would follow a straight line zenith-ward, it would transcend the distance of any known world probably, but finally not being supported in space by the action of the centrifugal or circular motion of the Sun, it would under its own weight, due to gravity, fall back to that body. However, an explosion of that character can not be instantaneous, it takes time for a mass of matter to travel thousands of miles far into the bowels of the Sun, just as it takes time even for light to travel in open space, and during that time the rotary movement of the Sun imparts to the body ejected the eastward motion which is to keep it aloft and alive for ever.

The force of the explosion, if very violent, is spent chiefly to give distance to the body, while a greater percentage of that force, if the explosion is milder, operates to give additional velocity to the eastward or circular movement of

the body. "Hence the slower circular motion around the Sun of the most distant planets and the swifter circular motion of the planets nearest to the Sun.

With a velocity in accordance with the force of the explosion, the body hurled into space will in time reach its mean distance from the Sun, then it will describe a curve whose most distant point will be its aphelion; following its eastward turning or curving movement it will come back gradually toward the Sun; in the course of its retrogression, again it will cross the mean line and will reach its perihelion or nearest point to the Sun. And thus the body will forever circle eastward around the equator of the Sun in an elliptical manner by swaying itself from aphelion to perihelion.

The later motion, from aphelion to perihelion is due to the momentum which carries the body beyond the limit assigned to it by the force of the explosion and its backward reaction. It is to be noted that an explosion from the Sun can not be strictly perpendicular and the least deviation from that line will react accordingly and change in one way or the other the form of the ellipse. Hence no two planets can be expected to have exactly the same ellipse, relative to their distance from the Sun.

A last feature which fits in with this theory is that any world, just elected to take its rank and file among the children of the Sun, will carry the unmistakable sign of its origin, which is to say, it will be hot and very hot for a long time to come.

Mr. Camille Flammarion has himself, unknowingly, established what seems to be the indisputable proof of the theory which infers that "the planets were exploded from the Sun." We refer to the table or statement in which Mr. Flammarion, POPULAR ASTRONOMY, page 215, has computed the time it would require for each planet to fall on the Sun and in which the multiplier 5.656856 plays so amazing a part.

We will remark here that a body falling back on the Sun returns with the same force which was expended to shoot it up. In other words, the velocity with which a falling planet would arrive on the Sun is exactly the velocity it has received when exploded from that body.

But the astonishing result of that masterly fact of calculation is the relation which Mr. Flammarion established between the velocity of the fall of each planet on the Sun with the velocity of their respective circular motion around that orb. Thus according to Mr. Flammarion's own figures the number of days which are required for a planet to fall on the Sun if multiplied by 5.659856 give exactly the period of time the planet takes to go once around the Sun. Here is that wonderful table.

Time of the fall of each planet on the Sun in days and fractions.		Length of the period of each planet net in days and fractions.
Mercury	15.55 × 5.656856 =	87.0692
Venus	39.73 × 5.656856 =	224.7008
The Earth	64.37 × 5.656856 =	365.2564
Mars	121.24 × 5.656856 =	686.9796
Jupiter	765.87 × 5.656856 =	4,332.5848
Saturn	1,902.03 × 5.656856 =	10,759.2188
Uranus	5,427.57 × 5.656856 =	30,686.8202
Neptune	10,628.73 × 5.656856 =	60,1267.200

Now, how could such a relation exisit, how could each piece of the wheel work of heaven fit the same mechanism if it had not the same origin, if it was not the handiwork of the same creative power.

NARCISSE ST. PIERRE.

GENERAL NOTES.

Owing to an extraordinary sale, No's 156, June-July 1908; 161, January 1909; 169, November 1909; 170, December 1909, are out of our files. Requests for these numbers have not been numerous enough to warrant the reprinting of any of the issues, but still a number of our subscribers need them to complete their files of POPULAR ASTRONOMY. If any of our readers, therefore, have made all the use they care to of these numbers, and care to dispose of them, we should be very glad to buy them back at the rate of 30 cents a copy.

Director W. W. Campbell of the Lick Observatory will spend the summer vacation in Europe. He expects to leave on June 9 and return about September 20. The greater part of the time will be spent in Germany, but he will visit also points in Switzerland and Italy. He will be accompanied by Mrs. Campbell and his three sons.

Dr. Keivin Burns, assistant at the Lick Observatory, has been appointed as the first recipient of the Martin Kellogg Fellowships. He will spend the coming year visiting observatories throughout Europe and in study and research at Bonn, Germany.

Dr. Ralph E. Wilson, who has for the past year been assistant editor, in active charge of POPULAR ASTRONOMY, has been appointed assistant at the Lick Observatory. He will begin work at Mt. Hamilton about July 1, 1911.

Dr. Lewis Boss, director of the Dudley Observatory, has been elected a corresponding member of the St. Petersburg Academy of Sciences. *Science*, May 12.

Mrs. A. H. Cruickshank, daughter of a former professor of Mathematics in Aberdeen University, who during her lifetime made generous gifts to the university, has bequeathed £22000 for the endowment of a chair of astronomy, the establishment of a science library and the provision of law prizes in the university, and the residue of her estate for kindred objects. *Science*, May 12.

Martin Kellogg Fellowships.—In the publications of the *Astronomical Society of the Pacific*, Director Campbell announces new fellowships established at the Lick Observatory by the late Mrs. Louise W. B. Kellogg, widow of ex-President Martin Kellogg, of the University of Cailfornia. "The gift was made in January 1908, nearly three years before Mrs. Kellogg's death, with the request that public announcement of the gift be not made until after her death. The fund consists of intesest bearing securities, with present income of about $1,200 per year. The conditions governing the administration of the Martin Kellogg Fellowships have not been determined, but it is probable that they will be available to meet the requirements of each successful applicant, as to amount of stipend, and as to place or institution of residence for study and research.

"Dr. Martin Kellogg's life was spent very largely in the service of the university and of the state of California. He was professor of Latin and Mathematics in the College of California from 1860-69; professor of Latin and Greek

in the University of California from 1869-76, professor of Latin language and literature in the University of California from 1876-93 and President of the University of California from 1893-99. In the latter year he resigned and was appointed professor emeritus of Latin. His death occurred in 1904. Dr. Kellogg took a lively interest in the science of astronomy in general, and in the work of the Lick Observatory in particular."

Such gifts as this have great value in the furtherance of the science of astronomy, in that they aid in the training of young men of brilliant mind who have not the means to pursue the long course of study which must precede any worthy advance in the science. There is need of just such gifts to every well equipped observatory.

Brooklyn Institute Elections:—At the annual meeting of the Executive Committee of the Department of Astronomy in the Brooklyn Institute of Arts and Sciences, the following officers were elected: Albert J. Brooks, president; Garrett P. Serviss, first vice president; Rev. Frederic Campbell, second vice president; and B. G. Way, secretary. Dr. Campbell continues to write the monthly astronomical articles and the weekly science illustrations for the *Boys World*, of Elgin, Ill., and the daily astronomical items syndicated throughout the world by the American Press Association.

William F. Rigge, Director of Creighton University Observatory, Omaha, Nebr., in a paper entitled "Is the Earth falling into the Sun," reprinted from St. Michael's Almanac, 1911, gives some interesting matter for the lay reader. The author shows that the present orbit of the Earth, both as to size and shape, cannot be changed to any appreciable extent. This is a fortunate condition for life on the Earth since any change would subject the Earth to extremes of heat or cold, and thereby probably destroy all life. Nor is it possible for the seasons to change, since the conditions of the Earth's inclination, which cause the seasons, can vary only within very narrow limits, and those variations which have large limits do not affect the seasons. The author points to these facts as evidence that there is an overruling Kind Providence He begins and ends with the thought that no real astronomer or scientist of any kind can be an atheist, or to put it into the words of Professor Young, 'An undevout astronomer is mad."

A New Star Atlas prepared by Arthur P. Norton and published by Gall and Inglis, London, has recently appeared. This seems to be a very complete reference work for occasional observers and amateurs. The maps contain more than 7000 objects including nebulae and clusters and stars down to the seventh magnitude. The places of these objects have been computed and charted for 1920. Besides the star maps the author has prepared fourteen pages of clear and concise statements concerning the various terms used in astronomy, and in answer to many questions that would arise in the mind of the amateur. There is also a list of 144 stars giving their common name and also their constellation name. A page is given to a table of the constellations and directions for locating them by indicating the dates on which they will cross the meridian at a given hour of the night. This, indeed, seems to be a very desirable volume to have at hand. It is quite substantially bound and can be bought for five shillings.